ENGINEERING NEWS
AND
AMERICAN RAILWAY JOURNAL.

Vol. XXXV., No. 13.

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A NICARAGUA CANAL BILL has been prepared by the House Commerce Committee. This bill provides for the reorganization of the Maritime Canal Co.; permits the company to issue bonds to the amount of $100,000,000, of which sum $7,000,000 is to be retained to reimburse the company for money actually expended in Nicaragua for their franchise. The United States guarantees the principal and interest of the bonds, and is to be protected in its liabilities by an issue of $100,000,000 of stock, which is to be the sole property of the government and must be deposited in the United States Treasury. Ten of the fifteen directors will represent the government, with the remaining five representing the company and the States of Nicaragua and Costa Rica. The Maritime Canal Co. must call in and cancel all its outstanding obligations, except the bonds issued to the two republics, aggregating $6,000,000. All bonds will bear 3% interest and the net earnings of the canal will be placed in a sinking fund for their extinguishment. The government will also have a first mortgage on the entire property and the canal construction and all work in connection with it must be done under the supervision of the War Department. The government reserves the right to purchase the $7,000,000 bonds held by the canal company.

THE PANAMA CANAL CO., through its American counsel, Mr. Wm. Nelson Cromwell, denies that there is any agreement, arrangement or plan for the consolidation of that company with the Nicaragua Canal Co. under any form of ownership or control. Mr. Cromwell explains that the new Panama Canal Co. is a private corporation and not a governmental organization, as some suppose. It has taken over the concessions from the old company, but is not otherwise connected with that company, and is an entirely new and solvent corporation prosecuting the enterprise purely as a business undertaking. It proposes to "neutralize" the canal, as was done with the Suez Canal, and afford all nations an equal opportunity for participation in its construction, operation and use.

SUEZ CANAL TRAFFIC IN 1895 is thus reported by U. S. Consul F. C. Penfield, of Cairo: Number of steamers, 3,434; net tonnage, 8,448,245 tons; traffic receipts, $15,631,748, an average of about $1.84 per net ton of traffic. English steamers numbered 2,330, Germany came next with 312 vessels, France sent through 274 and Holland 188 vessels. The American record covered only four warships and yachts. The total of vessels using the canal was 18 less than 1894, but the year 1895 was the most fruitful in receipts since the canal was opened to traffic. This is explained by the special traffic caused by the Chinese-Japanese war and the Madagascar and Abyssinian campaigns.

THE NEW YORK DOCK DEPARTMENT will build a masonry bulkhead and five new piers on the North River, between Charles and Gansevoort Sts., during the next year. To secure the property and wharfage rights along this line about $4,000,000 will have to be first expended; the average price paid being nearly $500 per lineal foot of front. Each pier is to be 100 ft. wide and 550 ft. deep, with 250 ft. between centers of piers. Upon them will be built double-decked sheds similar to those at the American Line pier. The piers will be constructed of wood, and the lifetime assumed for such a pier is 40 years, with a first cost of $35,000. A stone pier would cost nearly ten times as much; and while the wooden pier would pay for itself in rentals in about four years, the masonry pier would barely pay interest, says Secretary Bowen, of the Dock Board.

THE LOCATION OF THE NEW YORK AND NEW Jersey Bridge, across the Hudson River at 59th St., New York, has been approved by the Secretary of War. The location had been previously agreed upon by the Sinking Fund Commissioners of New York.

THE HUDSON HIGHLAND BRIDGE CO. is being organized in this city with the purpose of again taking up the project of bridging the Hudson River about three miles south of West Point. The construction of a suspension bridge at this point was authorized by the State in 1868, and some work was done four or five years ago upon the connecting line of railway. The present incorporators are: John W. Hazard, E. W. Serrell and Robert Serrell, of New York city; Henry Martin, Wm. G. Lord and James Pierce, of Brooklyn, and Wm. D. Snow, of Milford, N. J.

PLANS FOR THE NEW UNION STATION at Boston, Mass., mentioned in our issue of March 19, as proto take the place of the Boston & Albany, Boston & Providence, Old Colony and New England railway terminals, have been prepared by Shepley, Rutan & Coolidge, of Boston, who were architects for the existing union station at the north end of the city. The headhouse will be a four-story building, with a frontage of 350 ft. on Summer St. and 1,000 ft. on Federal St., and having a clock tower at the corner, the main entrance being at the corner. The trainshed will be 610 ft. wide and 850 ft. long, with 33 tracks and 17 platforms. Carriages will drive into the station under cover, and the sidewalks in front of the station will be roofed over. The main expense will fall on the New York, New Haven & Hartford R. R., which owns the latter three lines mentioned.

THE BRITISH PACIFIC RY. SCHEME has received a setback from the government of British Columbia, which has declined to give the financial assistance requested, on the ground that there is not sufficient guarantee as to the construction or success of the line, which was to extend across British Columbia and the Northwest Territory.

OIL FOR LIGHTING LOCOMOTIVE FIRES is being tried by the Pittsburg, Cincinnati, Chicago & St. Louis Ry., as a substitute for cordwood. A bucketful of waste soaked with about a gallon of crude oil is put in the firebox and lighted. Then a small quantity of coal is shoveled in and the blower turned on. By this method an engine can be ready in 25 minutes at a cost of about 3 cts. for oil and waste.

THE FILLING OF LOCOMOTIVE TENDER TANKS in as short a time as possible is aimed at by Mr. Charles Coda, Engineer of the Mediterranean Ry., of Italy, in a new arrangement of water cranes. These cranes are connected with elevated water tanks which give the desired pressure, while at busy stations, where many engines have to be supplied, it is proposed to use two tanks connected at the bottom by a pipe across the tracks, this pipe being fitted with a valve and hose over each track.

WATER FILTRATION IN PHILADELPHIA has been defeated for the present by a vote of 57 for to 49 against in the Common Council, two thirds being necessary. The proposition was to appropriate $250,000 for "one or more experimental or permanent filtering plants."

DOUBLE FILTRATION IS RECOMMENDED FOR Jersey City by Mr. Allen Hazen, of Noyes & Hazen, of Boston, as a means of rendering the sewage-polluted Passaic a safe water supply. The estimated cost for a 25,000,000-gallon plant is $980,000 for the two sets of beds, the first of 25 acres, uncovered, and the second of eight acres, covered; $25,000 for 100 acres of land; $50,000 for centrifugal pumps to lift about 10 ft., and $60,000 for 5,000 ft. of aqueduct to the main pumping station, making a total of $1,115,000. The cost per 1,000,000 gallons of operating the filter plant is estimated at $3.50 for the first and $1.25 for the second filtration, with $1 for the extra pumping, with no allowance for fixed charges. The report was made for the Jersey City Board of Trade and the Jersey City "Journal."

A NEW WATER SUPPLY FOR CINCINNATI has been reported on by Messrs. John W. Hill, Samuel Whitney and Geo. H. Benzenberg. It is recommended that the Ohio River be continued as a source of supply but that a new intake be adopted above the city. The proposed works include two 80,000,000-gallon pumping plants, large settling basins, filter beds, a clear water basin, high surface distributing reservoirs and the necessary mains, the latter to be of cast iron.

ANCHOR ICE HAS SCOURED OUT the interior of the 48-in. steel supply main of Newark, N. J., and increased its carrying capacity by about 1,000,000 gallons, or a little under 3%. This ice formed at the Macopin intake at the head of the main. Its passage through the pipe caused discoloration of the water. The flow is measured by Venturi meters, one at each end of the pipe. We are indebted to Mr. Morris R. Sherrerd, Engineer of the Newark Department of Water, for the above information.

TYPHOID FEVER AT WINDSOR, ONT., has become sufficiently prevalent to lead the Board of Health to declare the public water supply dangerous to health and recommend a Polarite filter. The Board is reported as just having adopted, at this late day, a regulation requiring physicians to report typhoid fever with other infectious diseases. It would be no wonder if an epidemic should spring up under such a lack of precaution for keeping informed of the prevalence of the disease. It does not appear that an investigation has yet been made which indicates that this may not be a milk instead of a water epidemic, but there seems to be evidence that the water is liable to pollution.

THREE BOILERS EXPLODED simultaneously at the Pine Ridge Colliery, Miners' Mills, Pa., on March 19. One went through a brick wall into the engine room and thence into an adjoining coal breaker. The second landed in the engine room, where it smashed the hoisting drum, and the third took an opposite direction, two-thirds of it landing outside on the railway tracks, and some pieces of it being thrown 1,000 ft. No one was killed.

A DEFECTIVE SAFETY VALVE caused the explosion of a boiler at McLarkin's Mill, in Wilcox Co., Ala., on March 17, killing three men. The boiler crashed through the mill and buried itself in the earth 400 ft. distant.

A GASOLINE TANK exploded in the purifying room of the gas works at Goshen, N. Y., on March 13, doing considerable damage. Windows of houses in the vicinity were broken by the concussion, and the report was heard a mile away.

AN EXPLOSION OF POWDER MILLS belonging to Laflin & Rand, at Rifton, about six miles from Kingston, N. Y., took place on March 18, killing five men, injuring several others and causing a loss of about $25,000. Two buildings known as the glazer and the dryer, out of 16 buildings in the works, were destroyed.

TWO EXPLOSIONS IN COAL MINES have been reported during the past week. The first was at the Ohio and Pennsylvania mine, at West Newton, Pa., on March 21. The mine was not in operation at the time, and the fire-boss and a water-boy went down the shaft to make an inspection, carrying a safety-lamp. The explosion took place 20 minutes after they descended killing them both. The second explosion was at the Berwind-White mine, at Dubois, Pa., on March 23. All of the men in one of the headings, 13 in number, were killed.

A NEW NATIONAL CODE OF RULES for electrical construction and operation was discussed at a conference of electrical, insurance and allied interests held at the rooms of the American Society of Mechanical Engineers, in New York, on March 17 and 18. It was attended by delegates from practically all of the national societies interested, including electrical engineers, fire underwriters, street railway, telegraph and telephone men and manufacturers. The codes of the National Electric Light Association, the National Board of Fire Underwriters, the Associated Factory Mutual Insurance Companies, together with rules of the Phoenix Fire Insurance Co., and the Board of Trade, both of England, were distributed to the delegates, printed in parallel columns in a large pamphlet for convenient study, and they formed the basis for an extended discussion. A permanent organization was formed to be known as the National Conference on Standard Electrical Rules, and a committee on rules was appointed to report at the next meeting, the date of which has not been fixed. The committee consists of Messrs. Francis B. Stone, Frank R. Ford, William H. Merrill, Alfred Stone, Captain W. Brophy, E. V. French and E. A. Fitzgerald.

A STATE ROAD BUREAU, for the State of New York, is proposed in a bill now before the Legislature. The State Engineer is to establish this bureau in connection with his own department and he is to appoint a civil engineer, expert in road construction, to take charge of this bureau at a salary of $3,000 per annum and expenses. The first duty of this new officer is to collate information relating to the state highways. He is to divide the state into divisions of one or more counties each and estimate the possible cost of road construction in each. He is authorized to obtain from the proper county boards or municipal officers, before July, 1896, the names and descriptions of all highways in their territory, their conditions, etc.

AN ELECTRIC INCLINED RAILWAY AT GREAT FALLS, MONT.

The Electric Street Railway Co., of Great Falls, Mont., has constructed a somewhat novel passenger elevator, or inclined railway, at that place, operated on the trolley system. It is intended to convey passengers from the approach of a suspension bridge over the Missouri River to the level of the railway tracks, about 100 ft. above this approach. This bridge connects the works of the Boston & Montana Consolidated Copper & Silver Mining Co., employing about 800 men, with the city of Great Falls. We are indebted to Mr. M. S. Parker, M. Am. Soc. C. E., and Consulting Engineer of Great Falls, for the following description of the elevator plant:

Economy in first cost and in operation were ruling conditions. The plant as built includes a tramway of standard gage, 400 ft. long, laid with 45-lb. rails on wooden ties. The angle of the incline is 22° 10″ with the horizontal. Parallel with this track is another track of the same gage, 200 ft. long, intended for a counterbalance car; the dead weight of the passenger car being 7,500 lbs., and that of the balance car and load is double this weight. A steel cable, 1 in. in diameter, is attached to the passenger car, and this cable passes around a sheave wheel, 5 ft. 6 ins. in diameter, placed horizontally at the top of the incline between the two tracks. This same cable then passes around a sheave of the same diameter fixed horizontally in the balance car, and thence to its anchorage above. By this arrangement the passenger car travels twice the distance of the balance car. The passenger car will accommodate 16 people.

Fig. 1.—Electric Incline Railway at Great Falls, Montana

The motive power used on this inclined railway consists of a 15-HP. old-type street railway motor (F. 30 single motor), with an overhead trolley. This motor is geared to the rear axle, the front axle being connected with the rear driving-axle by sprocket wheels and chain. The car is supplied with a friction brake, an automatic clutch-brake and a clutch-brake applied by hand, the clutch-brakes operating upon stringers bolted to the ties.

This plant was built in August, 1894, to replace a direct-pull drum hoist, without balance car attachment. The first plant was slow and unsatisfactory. The present arrangement enables a round trip to be made in two minutes, and has worked excellently since its installation.

Mr. Parker says that it is the steepest incline worked by electric power of which he has any knowledge; he had himself designed for this place a rack-and-pinion gear, single-track railway, worked by two 15-HP. motors, instead of the plant here described, which was designed by Mr. W. D. Dickinson, the Superintendent of the street railway company. Mr. Parker still believes that the rack-and-pinion system is to be preferred for such work, but the system here described is novel and economical, and is well worth putting upon record.

The views reproduced show the type of car employed and the general arrangement of the incline. On the right in the second view are seen the power wires connecting the smelting works with the electric generators, which are driven by water power.

TROLLEY CARS AND SURVEYING INSTRUMENTS.

We have received several letters from Mr. Charles S. Heller, of the firm of Heller & Brightly, instrument manufacturers of Philadelphia, calling the attention of engineers to a new danger to the compass needles of surveying instruments due to carrying such instruments in electric cars.

Engineers frequently set down the cases containing compasses or transits upon the floors of cars, forgetful of the fact that beneath this floor are two powerful electro-magnets, which may either partially or entirely demagnetize the compass needle; the damage done bearing a strict relation to the distance of the needle from the magnets and the length of time this needle is exposed to their influence. During the last four months, says Mr. Heller, at least 40 transits and compasses have been sent to his firm accompanied with the remark that trouble with the needle had followed the transportation of the instrument in a trolley-car. The north end of the needle would stick to the glass, and under some circumstances the polarity of the needle had been entirely changed by demagnetizing and recharging so that the north end pointed to the south.

As Mr. Heller explains, a compass needle is originally a simple bar of unmagnetized steel nicely balanced on a centerpin. When it is magnetized the north end, of course, "dips," and to counteract this dip a few coils of wire are usually wrapped about the south end of the needle. It is evident, then, that if the needle is demagnetized the effect of the magnetic "dip" is lost, and the needle is thrown out of balance, with the north end touching the glass.

To detect whether a trolley ride has effected the needle of his compass, the surveyor has only to try the balance of the needle upon the centerpin; if it is balanced no harm has been done. If the south end sinks, however, and the north end strikes the glass covering the compass, the needle has been affected and it should be sent to the maker for repair. For this purpose it will be sufficient to send the needle only, by registered mail.

Surveyors are advised to enter and leave trolley cars by the rear door, and to keep their instrument as far as possible from the motors, say, on the rear platform. Under no circumstances should the instrument be set on the floor of the car; if it must be carried inside the car it is better to put the box on a seat, or on the owner's lap. Neither rubber nor glass will protect from the magnetic effect; though rubber covers do insulate against electric currents, as do the rubber "bumpers" placed under all boxes. Needle instruments that are kept in modern very high office buildings are also liable to be affected injuriously, owing to the presence of electric currents and powerful magnets.

It is also well to remind the engineer that the needle may be made to stick to the glass by static electricity, produced by rubbing the glass against the clothes, or with a silk handkerchief. This effect is easily removed by discharging the electricity by the touch of a moistened finger to the glass. This experiment should be first tried in the case referred to, and if the trouble is not remedied by the needle at once resuming its normal position, then the needle has been demagnetized as heretofore explained.

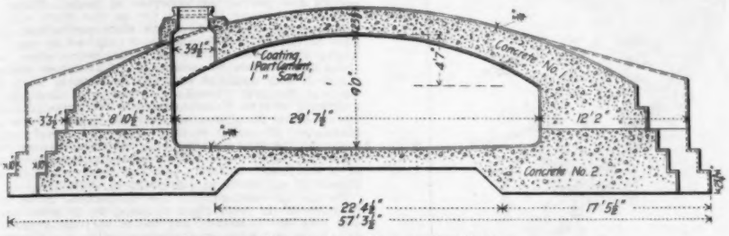
According to an item in the Philadelphia "Record" of Jan. 10, 1896, the U. S. Geological Survey is having trouble in determining the magnetic variation in Philadelphia. Chief Engineer Webster ordered the variation to be noted, in response to a request from the officers of the Survey. But the earth beneath the city is so filled with electric currents that the compass needles behaved in a most eccentric manner. If an electric conduit happened to be directly beneath the instrument the needle pointed directly downward. The variation desired was finally secured by taking the compass to a point in the 35th Ward, far removed from trolley wires and other electric influence.

LATE RAILWAY PROJECTS IN CHINA are commented upon as follows by Hon. Charles Denby, U. S. Minister to China, in a letter to the State Department. The Imperial decree of March 6 authorizes the construction of about 70 miles of railway between Tientsin and Lu Kou, eight miles west of Peking. The decree places the work in the hands of Hu Chufen, a protege of Prince Kung, at an estimated cost of about $28,000, gold, per mile. High embankments and numerous drains are the only difficulties in the way of construction; and an American engineer lately estimated the cost of this road at $20,000 per mile, with rolling stock and equipment complete. It is understood that Mr. Hu is instructed to employ no foreign capital. The decree practically orders the formation of native stock companies for railway building, and this provision outlines the present railway policy of China. While the government seems to be now determined to exclude foreign capital and control, in this connection, the very magnitude of the work undertaken and the inefficiency of native methods will very probably soon compel a change of management and open a great field to foreign railway enterprise. Mr. Denby advises Americans to carefully watch this development.

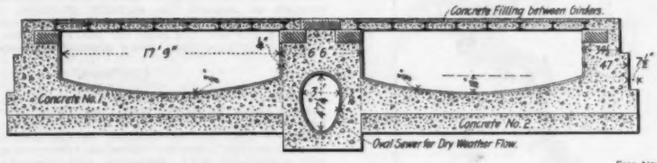
FIG. 2.—CAR FOR ELECTRIC INCLINE RAILWAY.

A CONCRETE STORM-SEWER IN BRUSSELS, BELGIUM.

While American engineers are all the time extending their use of concrete, and have applied it in many ways which were hardly thought of a dozen years ago, they still make little use of it for works of very large size. In Europe, however, the use of concrete in place of masonry for large structures has become very common. In the city of Brussels, Belgium, some very large concrete works were carried out last year to carry the storm flow of the Maelbeek Creek, a stream which flows through an important section of the city and which carries a great volume of water after every heavy rainfall.



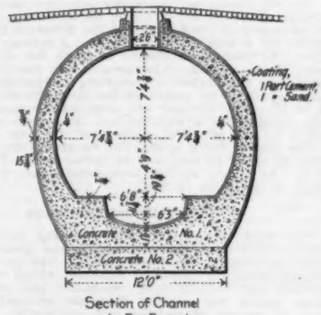
Section of Channel under Brussels Gas Works.



Section of Double Channel under State Railway.

ENG. NEWS.

FIG. 1.—CONCRETE CHANNEL FOR MAELBEEK CREEK, BRUSSELS, BELGIUM.



Section of Channel under Rue Portaels.

The channel was constructed of different forms at different points to suit local conditions, and we give herewith cross-sections of these different forms (Fig. 1). It will be seen that one of these channels has a clear width of almost 30 ft., and another has an approximately circular section of about 15 ft. diameter. Our illustration, Fig. 2, is reproduced from a photograph taken in the interior of this channel.

A remarkable feature of these works is the small proportion of cement used in the concrete with which they were built. The No. 1 concrete was made of 8 parts gravel, 4 parts sand and 1 part cement, while No. 2 was made of 12 parts gravel, and 6 parts sand to 1 of cement. This latter grade, however, is used only for the foundations, and it will be noticed that all the work received a finishing coat of 1 to 1 mortar. The cost of the No. 1 concrete was 24 frs. per cu. m. ($3.56 per cu. yd.) and the No. 2 cost 21 frs. per cu. m. ($3.11 per cu. yd.). The cost of gravel (no pieces exceeding 1¼ ins. diameter) averaged 4.60 frs. per cu. m. (70 cts. per cu. yd.) and sand cost a trifle less. The gravel or shingle which forms the bulk of the aggregate is preferred to broken stone, as it has a much smaller percentage of voids.

Some further particulars concerning the work are given in the following translation of a description of the work in "L'Etoile Belge," of Brussels, dated April 18, 1895:

> The works for the improvement of the regimen of the Maelbeek Creek, lower section, between the Place Verboeckhoven and the River Senne advances with remarkable regularity and rapidity. We visited the day before yesterday the lower part of the section, the vast line of work situated within the enclosure of the Brussels gas works.
>
> In the first place a dyke of enormous piles closes the River Senne. At this point an inclined plane 50 ft. in length will form the junction of the work with the river at the end of a curve of 328 ft. radius and 480 ft. long. Above the junction with the river the concrete arch is finished and the centers have been struck for a distance of 350 ft. This arch has a normal section 29.5 ft. in width with a height of 4 ft. to the springing line, and a rise in the arch of 4 ft. 5¼ ins. Adding to this the fall of the invert, say 6¾ ins., we have then a clear height along the axis of 9 ft. This tunnel, lighted from point to point by shafts, makes one think of a subway for city traffic. One would never believe that this considerable work is reserved for a capricious little creek, for the most part dry, like the Maelbeek. Thanks to the grade, which is 1 in 250, the flow will respond to the greatest rise in storms which can possibly be expected, and all danger of inundation is forever dismissed for the future.
>
> The thickness of the arch at the keys is 23½ ins. The concrete is composed of 1 part of Portland cement from Beerse, with 4 parts of Rhine sand, very rough and quartzose, and 8 parts of the Rhine gravel; which mixture requires 350 lbs. of cement to a cubic meter of concrete. This formula permits of the construction, at the same price as ordinary masonry of monolithic works, as solid and as unassailable as if they had been cut in granite; thanks to the constituents chosen in building the work. Let us add that our Belgian cement from La Campine, made from the chalk of Vise, surpasses all similar products from Germany, England and France.
>
> The arching of the lower part of the Maelbeek is done at the cost of the city, which will enjoy the use for the gas works, of the ground surface over the arch as well as the old filled-up bed of the creek.

We are indebted to Messrs. Edwin Hall & Co., 305 Walnut St., Philadelphia, Pa., the American agents for North's Belgian Portland cement, for the drawings, photographs and information from which the above description has been prepared.

FIG. 2.—VIEW OF INTERIOR OF CHANNEL UNDER RUE PORTAELS.

THE SIZE OF INJECTION PIPES FOR CONDENSERS.

By A. F. Nagle, M. Am. Soc. M. E., Chicago, Ill.

The size of an injection pipe is governed by the height of lift of water and the length of pipe. As ordinary conditions prevail—i. e., when the water supply is near to the condenser, the makers of condensers have followed a practice which experience has shown to provide pipes of ample size; but should the conditions be somewhat different, the size of pipe provided by makers will be found to be inadequate in size. The writer has found the size of openings provided by several standard makes of condensers to be too small for certain practical conditions, and has therefore computed the following table, which would guide the engineer somewhat in determining the size of injection pipes. It will be observed that the length of pipe used in this calculation is not very great, and only three elbows are allowed for in using this table; this should be borne in mind, and the table is only reliable for the conditions explained herein. The other data within the table are self-explanatory, and the engineer will find no difficulty in its use.

Proper Sizes for Injection Pipes. (Computed by A. F. Nagle, M. Am. Soc. M. E.)

(This table is calculated upon the following data: That the engine consumes 20 lbs. of steam per I. HP. per hour; that 25 lbs. of condensing water are required per lb of steam; that the condenser vacuum equals 11½ lbs., or 26.5 ft., below atmosphere; that the "total loss of head" equals six times the velocity head, which allows for pipe lengths of 75 diameters and three elbows.)

Condensing water per second equals .014 lbs., or .0167 gallons per I. HP.

Hot water has to be lifted, ft.	8	13	17	20	23
Vel. of flow, ft. per sec.	14	12	10	8	6
Pipe diam., ins.	Horse-power —of engine which pipe will supply.—				
2	145	125	104	83	63
2½	210	180	150	120	90
3	320	275	230	185	140
3½	430	370	308	245	185
4	545	470	390	310	235
4½	700	600	500	400	300
5	850	730	610	490	365
6	1,230	1,050	880	700	530
7	1,680	1,450	1,200	960	720
8	2,180	1,870	1,560	1,250	935
9	2,800	2,400	2,000	1,600	1,200
10	3,400	2,900	2,440	1,950	1,460
12	4,900	4,200	3,500	2,800	2,100
14	6,700	5,760	4,800	3,800	2,900
16	8,700	7,500	6,200	5,000	3,700
18	11,000	9,600	8,000	6,400	4,800
20	14,000	12,000	10,000	8,000	6,000

THE REPORT OF THE NICARAGUA CANAL BOARD.

The report of Col. Wm. Ludlow, U.S. A., Mr. M. T. Endicott, Civil Engineer, U. S. N., and Alfred Noble, M. Am. Soc. C. E., who were appointed by President Cleveland to examine the feasibility of the Nicaragua Canal Company's enterprise, has been issued in a pamphlet of 103 pages, but in so limited an edition that it is practically inaccessible to engineers generally. We have, therefore, decided to reprint in full such parts of this report as discuss in detail the engineering features of this important enterprise, and have added eight additional pages to this issue of Engineering News in order to do so without encroaching on our regular reading matter contents.

The Board's report was accompanied by 34 plans and profiles and 12 appendices, none of which have been printed. In order to make the report more intelligible to the reader and familiar with Nicaraguan geography, we have reproduced the best and most correct map of the line of the canal that we have been able to secure and present it herewith. Among the appendices omitted in the printed report are records and a summary of river-gagings, rainfall observations, the Serapiqui River reconnoissances, notes on volcanoes and earthquakes in Costa Rica and Nicaragua, by Prof. Henry Pittier, correspondence with the canal company, etc.

From the prefatory matter it appears that the Board arrived at Greytown May 13 and sailed from there on June 24, the intervening time being spent in an examination of the canal route. The Board also inspected the Costa Rica Ry. and the Panama canal works, and returned to New York July 21. The following months were occupied in the preparation of the report.

GENERAL PHYSICAL DESCRIPTION OF NICARAGUA.

Characteristics of the Nicaragua Basin.

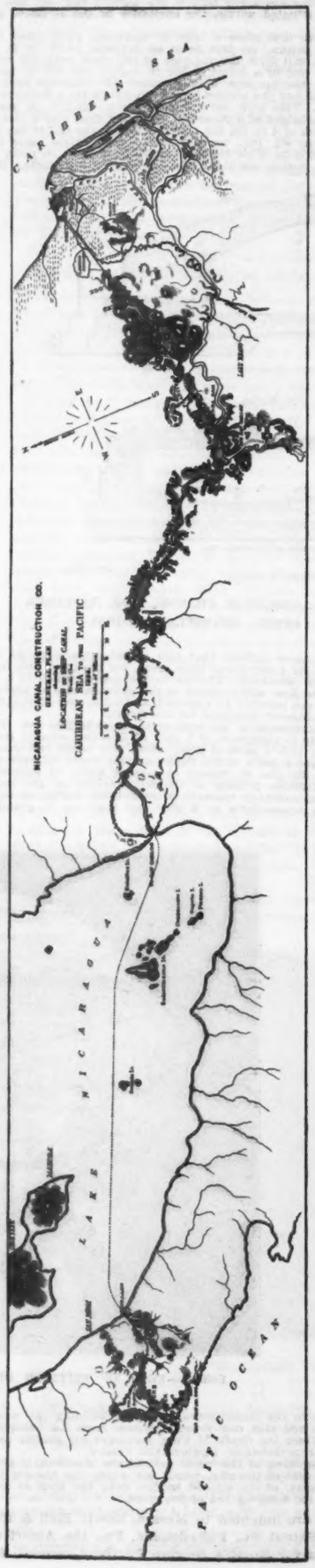
The cordillera or mountain ridge that divides the Pacific drainage from that of the Atlantic, having crossed the northwest boundary of the state of Nicaragua and reached a point about 35 miles north of Managua, separates into two branches. The eastern divide, continuing the general southeast course, parallel with the northeast shore of Lake Nicaragua, and 20 miles distant from it, bears directly toward Greytown, on the Caribbean coast; sending a spur across the San Juan Valley at Ochoa, and terminates on the borders of the San Juan delta.

The western divide, first inclining southwest for about 50 miles toward the Pacific, heads Lake Managua, and thence goes southeast parallel with the Pacific coast, at an average distance of 10 miles, to connect with the main divide in the high ranges of Costa Rica. The rectangular basin, inclosed on three sides by the two divides, has a length northwest and southeast of, roughly, 200 miles, with an average width of about 60 miles, and an approximate area of 12,000 square miles, covering Lakes Managua and Nicaragua and the territory draining into them.

There are no maps of Nicaragua based on accurate surveys, and scarcely any two agree. The distances, areas, etc., noted may, therefore, be considerably in error. Lake Managua has a length of about 35 miles and a maximum width of 20, and discharges into Lake Nicaragua across the neck of land 14 miles wide that separates them, through the Tipitapa River, which has a length of 23 miles and a fall of about 25 ft. from one lake to the other. During the dry season the visible outflow from Lake Managua disappears and the bed of the Tipitapa is dry, and such surplus of supply over evaporation as may exist must escape through fissures in the rocky bed. Lake Nicaragua has a length of 110 miles and a maximum width of 45, and an area of about 2,700 sq. miles. The only outlet for the drainage of the basin is the San Juan River, which leaves Lake Nicaragua near its southeast end, and discharges through the several channels of the delta which it has built out into the Caribbean Sea.

The San Juan is a fine stream of large volume even at low water, an average width of 300 yds. and total length of 120 miles, flowing between stable banks clad with dense tropical vegetation, and is navigable for river steamers throughout its length, with the exception of some rapids in the upper portion that at low stages interrupt the passage of boats. The valley of the San Juan on the north is limited by the east divide until the head of the delta is reached. It is therefore narrow and hilly and the affluents small. On the south side the conditions are reversed. The drainage area is bounded by the lofty crest line of the Costa Rican range 40 or 50 miles distant; the streams are large and torrential and in times past have brought down great quantities of sand and volcanic detritus. In the upper reaches between the rapids the current is moderate, the bottom firm, and the water clear, but these characteristics change from where the San Carlos comes in, below which the bed of the San Juan River is of sand and the current turbid and strong. The main volume of the river reaches the sea through the Colorado, leaving little more than 10% to reach Greytown by way of the lower San Juan.

Lake Nicaragua is notable for its general dimensions, for the moderate elevation of its surface above sea level, and for the proximity of its west shore to that of the Pacific. The strip of land separating them is at the narrowest but 12 miles across, and at one point on the divide the elevation, 154 ft. above sea level, is less than at any other that has been discovered on the isthmus. These facts, in conjunction with the navigability of the San Juan River, which furnishes access to the lake from the Caribbean and permits vessels to reach a point so near to the Pacific, have from the earliest times attracted attention and given prominence to the Nicaragua route as a feasible means of communication across the isthmus.



MAP OF THE NICARAGUA CANAL.

The lake has not been surveyed either for coast line or hydrography, but enough is known to warrant the conclusion that its general depth is ample for all purposes of navigation. At the southeast end, behind the Solentiname group, the shores are low and the lake becomes shallow, with a soft bottom. At 14 miles from shore the soundings show 22 ft. at mean low lake, diminishing to 6 ft. a mile from Fort San Carlos, where the San Juan has its outlet.

The geologic history of the Nicaraguan basin is obscure. Glacial action, submergence, emergence, volcanic eruptions, and seismic convulsions have all played their part in the tumultuous and chaotic past, to confuse the record and puzzle the observer of to-day. There is good reason to believe that, so far as the more violent phenomena are concerned, which were centralized along the line bordering the Pacific, now marked by the range of peaks at frequent intervals, the forces that produced them are practically exhausted. The latest volcanic outburst of any moment was 125 years ago, when the volcano of Masaya, 15 miles northwest of Granada, poured a stream of lava 10 miles toward Managua. Momotombo, rising 6,000 ft. above sea, on the north shore of Lake Managua, 90 miles distant from the canal route, and some of the still loftier Costa Rican volcanoes, 60 miles or so southeast from Lake Nicaragua, still give evidence of a moribund vitality; but the intervening peaks seem almost if not quite at the point of extinction.

As far as earthquakes are concerned, it is true that tremors occur from time to time, as in other countries, our own for example; but for a very long period there has been no such destructive action in Nicaragua as accompanied the Charleston earthquake. There seems no reason, therefore, to apprehend a disturbance serious enough to imperil the stability of canal constructions, at least any of such moment and imminence as would warrant the abandonment of the enterprise, if in other respects its execution were deemed advisable.

Harbors.

The west coast of Nicaragua has excellent harbors, the best of which, however, viz., the Gulf of Fonseca and the bay of Salinas, lie at the territorial limits of the state. The principal one is Corinto, in the northern province of Chinandega, whence there is communication by rail and steamboat with Managua and Granada. San Juan del Sur, eight miles southeast of Brito, is small and with steep slopes inland. Brito is merely an indentation in the coast line at the mouth of the Rio Grande.

On the Caribbean coast the principal harbor is Bluefields, about 70 miles north of Greytown, where there is an ample inclosed bay, and the Bluefield River is navigable for a long distance inland. A railway is projected from the head of navigation to reach San Ubaldo, on the east shore of Lake Nicaragua. The condition of what once was the harbor of Greytown is elsewhere stated in this report. The mouth of the Colorado has a depth of 8 to 12 ft. on the bar and ample harborage inside, but the entrance is a shifting and dangerous one, complicated by the powerful current of the river and the detritus carried down by it. The range of tide in the Caribbean is about 15 ins., and at Brito, on the Pacific, about 9 ft. As nearly as has been determined, the mean sea level is the same in both.

Rainfall and Drainage

The most serious problems affecting the design and construction of a canal system at the present time are those involved in the heavy rainfall and consequent discharge from the lake and streams, whose variations of surface and volume must be taken into account. On these points the existing data are seriously defective, both in respect of number and continuity. There is a rainfall record at Greytown for the three years, 1890, 1891 and 1892, which shows a mean of 267 ins., a maximum of 297, and a minimum of 214. A record at Rivas, on the west side, kept by Dr. Flint, an American resident, for the years 1880 to 1894, gives a mean of 65 ins., a maximum of 105 and a minimum of 32. In addition to these, there is reliable information of precipitations of 3 ins. in an hour, of 9 ins. in 9 hours, and 35¼ ins. in 8 days. A record of nearly 25 ft. of water in a year on the Caribbean coast, diminished to 5½ ft. between the lake and the Pacific, needs no comment to indicate the important results that must ensue with reference to matters of local drainage and engineering constructions. It would be of value if intermediate points had been occupied, and the diminution of rainfall traced from Greytown to Brito, but the observations in this respect are scattering and unsatisfactory.

The height, cross-section and volume of cuts, dams and embankments, and the dimensions of locks, weirs and sluices to be constructed for the maintenance and utilization of the summit level, the precautions to be taken to make these works secure, and the loss in elevation of water surface due to droughts or deficiency—all these depend for their determination upon the fullest and most precise gagings of all the water courses concerned, following their variations of volume and velocity throughout their range; and, even with these most carefully ascertained, allowance would still have to be made for possibilities occurring at long intervals. This information has not been secured. The survey by Colonel Childs in 1851, and that by Commander Lull in 1873, made some gagings during the brief period of the field work, but took account mainly of low-water data only, to determine if there was a sufficient supply for an ordinary low-level canal. The canal company has omitted attention to these matters, and made no careful gagings at any point, and this omission is the more to be regretted, because the company's project calls for the construction of numerous dams and embankments of magnitude, some of them without precedent in engineering practice, and all involving serious hydraulic problems.

While the variations of precipitation are great, the average annual cycle in Nicaragua is fairly simple. The rainfall follows the sun; greatest when passing the zenith; less when farthest north, least when farthest south. This gives a "wet season," beginning in late May or early June, culminating in July and August, diminishing in September, increasing again in October and November, and falling off in December. From January to April, inclusive, is the "dry season," a nominal one at Greytown, where rain may fall on any day in the year, but much more marked on the west side, where for several months the rainfall will be small or intermitted altogether. In the former case the air is always humid; in the latter it may be dry and parching for considerable periods, with corresponding effects upon vegetation and soil.

Climate.

The climate of Nicaragua is commonly misunderstood, and it is not realized that every summer in the United States gives a thermometric record higher than at any time in Nicaragua, where it seldom exceeds 90° or falls below 70°, making an average range of about 20°. These temperatures, which represent what would be a moderate summer heat in the United States, in Nicaragua continue throughout the year, and it is this fact, in connection with the high humidity, that so seriously reduces the value of physical labor in the Tropics. The trade winds blow from the sea with a mild persistence that is very grateful in the shade, but prolonged exertion is exhausting, and the net product is much less than in temperate zones. It is important that account of this fact be taken in estimating for the cost of the work.

The question of healthfulness must also be referred to in this connection. There seems little reason to believe that the general conditions in Nicaragua involve any special rate of mortality. So far as statistics are attainable, they indicate healthful conditions and the absence of epidemics. There has never been any yellow fever at Greytown, for example, except when imported, and those cases were readily isolated and cured. The prevalent diseases are mild types of remittent and intermittent fevers, occasionally of a pernicious and fatal type. There is no typhoid. Consumption is rather frequent, and skin diseases common among the natives.

The causes of this comparative exemption from the curses of other tropical climates are probably two: The trade wind blowing with much steadiness landward constantly renews the atmosphere with the sweet sea air, and carries off or dilutes unsanitary emanations. The heavy rainfall washes the air and furnishes an abundance of fresh drinking water condensed from the ocean vapors.

With pure water and pure air and a moderate equable temperature, the hygienic conditions are certainly favorable, and only human ignorance and neglect of sanitary precautions would cause an excessive mortality. These are the normal and natural conditions, which, however, may be greatly modified when excavations are made, the rich humus, charged with decomposing vegetation, exposed, and the malarial fungoids taken up by the atmosphere. It is in these conditions that have occurred the heavy death rates on the Panama Railway and Canal, and, as ascertained by the Board, on the line of the Costa Rica Railway from Port Limon to San Jose. The natives suffer from these artificially produced endemics or epidemics as well as foreigners, and, as might be expected, it is the Jamaica negro who comes nearest to securing exemption. When the railway was building, great drafts were making on the Jamaica population for the Panama Canal, and labor was sought elsewhere. The United States negroes were neither procurable in sufficient numbers nor adapted to the climate. The Chinese imported are stated to have died like sheep, and of a large number of Italians brought in but a small proportion ever returned.

In case of building the Nicaragua Canal, it will be needful probably to call upon the population of Jamaica for the necessary labor. This is represented to be about 400,000, and 15,000 or 20,000 could be brought over under contract. They make good laborers when well handled and controlled, as compared with other inhabitants of the Tropics, and adapt themselves more rapidly to new conditions. The Nicaraguan natives are less effective for work to which they are unaccustomed. They make excellent porters, woodsmen and river boatmen, but for labor with pick and shovel or a barrow would be found undesirable and probably not procurable at all. For the working camps, the sanitary requisites would be an ample supply of fresh rain water delivered on the ground, and good food, with plenty of plantains and fruit; shelter and dry floors, dry bedding, ample bathing facilities, and no grogshops.

GENERAL DESCRIPTION OF THE NICARAGUA CANAL PROJECT.

The canal project now under consideration is a gradual development due to successive investigations made at intervals during the past fifty years, and, for a better understanding of the matter, the history of these may be briefly reviewed.

The Childs Project—1852.

The first authentic survey and actual location of a canal route across Nicaragua were made by Col. O. M. Childs in 1850, 1851, and 1852, at the instance of the then existing Transit Co., which had established transisthmian communication with California by steamer from Greytown via the San Juan River to Virgin Bay on the west shore of Lake Nicaragua, and thence by stage to San Juan del Sur, a small natural harbor on the Pacific coast, about eight miles southeast of Brito. The river navigation proved troublesome and uncertain at low stages, and the Transit Co. sought means to better these conditions, and to continue the water route across the narrow neck of land that separates the lake and the Pacific, with the object of securing a continuous depth of 17 ft.

Colonel Childs, an expert canal and railway engineer, of high repute in his day, was engaged to make the surveys, and his report, which has constituted the basis of all subsequent investigations and is still a valuable source of original information not elsewhere found, evinces the thoroughness with which his work was done. He examined the several possible routes between the lake and the Pacific, and decided in favor of a line via the Rio Grande and Lajas Rivers—the former an ocean and the latter a lake affluent, between the head waters of which the divide was lower and the route more practicable than at any other point. The line determined Brito, at the mouth of the Rio Grande, as the Pacific terminus, notwithstanding its lack of natural advantages as a harbor.

Childs found the ordinary high level of the lake to be about 108 ft. above mean sea level, and proposed to hold it at that elevation by means of two dams, one at Buen Retiro, in the Rio Grande Valley, 9¾ miles west of the lake, and the other at Castillo, in the valley of the San Juan, 37¼ miles east of the lake. The distance across the lake from the mouth of the Lajas to Fort San Carlos, where the San Juan River leaves it, being 56½ miles, the total length of summit level, was 103⅓ miles. To continue the canalization of the San Juan below Castillo were six more dams, the lowest at a point one-half mile below the mouth of the Serapiqui, and 91 miles from the lake, where the canal was to leave the river and follow its left bank to Greytown, at that time an excellent harbor.

The difference of elevation between summit and sea level was to be overcome by 14 locks on each side, with a maximum lift of 8 ft. The total length of the proposed navigation was 194.4 miles, made up as follows:

	Miles.
Canal between Brito and the lake shore	18.6
Across lake, Lajas to San Juan River	56.5
Slack water in San Juan by seven dams	90.8
Canal to 17 feet water in Greytown	28.5
Total	194.4

The locks were to be 250 by 60 by 17 ft., the bottom width of the canal 50 ft., increased to 90 ft. at turn-outs, and of excavated channels in river and lake 150 ft. The total estimated cost of the project, including 15% for contingencies, was $31,538,319, based on the supposition that on the average the expense for construction would be about double the cost of similar work in the State of New York. In a supplementary report, Colonel Childs provided for raising the summit level 3 ft. higher, viz., from 108 to 111, by making a corresponding increase in the height of the terminal dams at Buen Retiro and Castillo, with the object of reducing the cost of deepening the navigation in the upper 37 miles of river and out to deep water in the lake.

The Lull Project—1873.

In 1872 a United States Government expedition was fitted out for the re-examination of the Childs route. The final report of the exploration, including location and estimates for a canal, were made under date of December 1, 1873, by Commander Lull, U. S. N., with whom was associated as chief civil engineer Mr. A. G. Menocal, the present chief engineer of the canal company.

The Lull project contemplated a canal of 26 ft. depth. It lowered Childs's summit level to 107 ft. and on the west side, instead of the Lajas, adopted the valley of the Medio, a lake affluent 3½ miles to the northward, as a means of reaching the valley of the Rio Grande, which was thence followed to Brito. The Medio had a much higher divide than the Lajas, involving more excavation, but was a trifle shorter, and believed preferable as a means of avoiding interference with the canal by the discharge from the upper valley of the Rio Grande. For the ascent to the lake, 11 locks were projected, with a maximum lift of 10½ ft. For the canalization of the San Juan 4 dams were to be built; the uppermost at Castillo, the lowest at a point 66½ miles from the lake and 1 mile below the mouth of the San Carlos River. To avoid complications from the discharge of this important stream, it was proposed to cut a new channel for it to the San Juan River below the dam. The canal was to leave the river at this point and follow the left bank to the outlet of the San Juanillo, and thence to Greytown by an almost direct course. Ten locks of maximum lift of 10.87 ft. furnished the means of descent from the lake to the Caribbean.

The total length of the Lull summit level was 102 miles, and of the navigation from Brito to Greytown 181¼ miles, made up as follows:

	Miles.
Canal from Brito to lake at mouth of Medio	16¼
Across the lake, Medio to San Juan River	56½
Slack water in the San Juan by four dams and short canals	66¼
Canal to Greytown	42
Total	181¼

The locks were to be 400 by 70 by 26 ft., the bottom width of canal 50, 60, and 72 ft. in different sections, of excavated river channel 80 ft. and lake channel to — ft.

As Greytown Harbor had been destroyed since Colonel Childs examined it, the cost of its restoration, including an item of $100,000 for shutting off the Lower San Juan River from the harbor, was estimated at about $2,500,000, and the estimated cost of the entire project, including 25% for contingencies, was $65,722,147. The instrumental work by the Lull survey was not adapted to much more than a preliminary location, the levels were not checked, and for the 66½ miles of river to the lowest dam below the San Carlos the transit and level line covered about 26 miles only, the remainder being run with a gradienter, used by the hydrographic party under Lieutenant Miller, U. S. N. The unit prices used in computing cost, as is to be inferred from a statement in the report by Mr. Menocal to Commander Lull, were apparently based on the supposition that they would not exceed those for similar work in the United States.

Mr. Menocal's Project—1885.

In 1885, Mr. Menocal, under government direction, made a partial re-examination and location, and the results are given in his report of November of that year. The project was for a depth of 28 ft. and in some places 30 ft. On the west side the route adopted was substantially the original one of Childs via the Lajas and Rio Grande, provision being made for the diversion of the upper course of the latter stream. The summit level in the lake was to be raised to an elevation of 110 ft. above mean sea level, and this height overcome by four locks with a maximum lift of 33 ft.

For the canalization of the San Juan a bold measure was proposed, viz., the construction at Ochoa, a point 3½ miles below the San Carlos River and 69 miles distant from the lake, of a dam in the San Juan River which would have a height of nearly 60 ft. above water surface, and by flooding the valleys of the San Juan and San Carlos convert them into an extension of the lake itself, whence the canal could abandon the river altogether and go eastward at the higher elevation directly toward Greytown.

To provide both for the maintenance of the lake level at 110 ft. and for the discharge of the San Juan, a slope of 4 ft. was assumed for the entire distance, and it would therefore be at the elevation 106 ft., or about 60 ft. above the river at low stage, that the canal would leave it and carry the water level eastward. In order to do this it would be necessary to build extensive dams across the valleys of several small streams, the San Francisco being the largest, which discharge into the San Juan, and convert them into basins connected by short lengths of canal, and beyond these constructions to cut through the eastern divide, with a maximum depth of about 320 ft., in order to reach the valley of the Deseado, flowing toward Greytown. The distance through the basins from the San Juan to the west side of the divide cut is 12 miles, and through the divide cut three miles, whence descent is made in the Deseado Valley to sea level by means of three locks, one of which has a lift of 53 ft., and by a canal 16½ miles in length to Greytown. By this bold expansion of the earlier projects a material shortening of the line would be effected, as well as a valuable extension of the unobstructed navigation of the summit level.

The total distance from Brito to Greytown is stated at 169.8 miles, made up as follows:

	Miles.
Brito to lake	17.27
Lake Lajas to San Juan	56.50
Slack water in the San Juan	64.54
San Francisco Basin Ochoa to eastern divide	12.01
Cut through the eastern divide	3.00
Canal to Greytown	16.48

The total length of summit level is given at 144.8 miles.

A discrepancy in river distance between the lake and Ochoa, more particularly referred to hereafter in the detailed account of the river navigation, occurs first in the report of 1885, and calls for an addition to the length of summit level, and to the entire navigation of about four miles. Lull used about this length of short canal in the river, and deducted it from the river navigation proper. This reduced river length has by inadvertence been carried forward into the 1885 and subsequent reports as the total length of the river navigation. Making the correction the summit level would be about 149 miles and total navigation from sea to sea 174 miles. As designed in 1885, the locks were to be 650 by 65 by 29 ft.; the bottom width of canal 80 ft., increased at the terminals to 120 ft.; of excavated channel in river 125 ft., and in lake 150 ft.

The estimated cost of the project, including 25% for contingencies, was $64,036,197; but the item for contingencies is made to include the cost of surveys, hospitals, shops, management and other necessary expenses, in addition to the construction contingencies proper. It is admitted in the text of the report that the cost of work in Nicaragua should be estimated as greater than in the United States, but the unit prices adopted do not indicate that the necessary allowance has been made in all cases. No borings were made to ascertain the depth of foundation, presence of rock, distribution of materials, etc. The Ochoa Dam was to be built of concrete, with foundations 20 ft. below the river surface, the depth of water varying from 6 to 17 ft., but the nature of the subjacent river bed was not ascertained, nor was it then known that to retain the water level in the San Carlos Valley at 106 ft., an extensive system of embankments would be required along its eastern watershed.

Canal Company's Project—1890.

Under the direction of the company, eight survey parties were employed from Dec. 1887, to June, 1888, when the number was reduced to two or three. A still larger force worked from the spring of 1889 to the summer of 1890, when the parties were gradually dispensed with, and the last one withdrawn in 1891. Borings were continued to as late as 1893. The eight parties comprised six land parties, one hydrographic party and one boring party. Borings were made along the line of the canal; the western division, lake to Brito, was relocated, and Greytown Harbor surveyed. Brito Harbor and the east and west sides of the lake were examined and the San Carlos Valley and east crest line explored. A low-level line in the San Juan Valley was located eastward from the Ochoa Dam, but most of the survey work was directed to developing the difficult topography over the high-level line through the San Francisco Valley and the east divide cut along the line originally proposed by Mr. Menocal in 1885.

The resulting project as set forth in the final report on location by the chief engineer under date of January, 1890, and further elaborated in a paper prepared by Mr. Menocal for the Chicago Water Congress in 1893, is substantially that of 1885, with some modifications and an important addition. Additional basins and dams are added in the Deseado Valley east of the divide cut, provision is made for embankments along the east crest of the San Carlos Valley to retain its flowage line at an elevation of 106 ft., and most important of all, the extension of the summit level westward from the lake is provided for by the construction of another high-level dam at La Flor, a contracted point in the Rio Grande Valley 3.8 miles from the Pacific, converting the valley above into a basin 4.6 miles long at the lake level, and making a corresponding reduction in the length of excavated canal.

The elevation of the summit level is retained at 110 ft. and its length increased to 153¼ miles, the total distance from Brito to Greytown being 169½ miles.

The company's surveys, other than the borings, were mainly topographical and did not include the procuring of hydraulic data. Few gagings of value were made for this purpose, and there was no survey of the San Juan at all, or endeavor to ascertain its regimen, or of that of the lake.

The total cost of the canal is stated in the company's estimate of 1890 at $65,084,176, including 25% for contingencies, which, however, as in 1885, cover the cost of shops, hospitals, and management also. The unit prices used are in general somewhat less than those of 1885. The company's estimates include an item of $275,000 as representing the cost of a canal to connect Lakes Nicaragua and Managua via the Tipitapa River. The connection constitutes no portion of the ship-canal project, and has not been investigated by the Board. Its appearance in the company's schedule is due to a requirement in the concession from the Nicaragua government. There are no estimates of the damages that may be incurred by reason of the submergence of lands, and in the absence of any data the Board has not endeavored to ascertain what amount should represent this item.

Subsequent to the final report of 1890 several important changes have been made in the project as indicated in the Chicago paper above referred to, in the Board's correspondence and interviews with the chief engineer, and otherwise. These may be briefly referred to. The company's recent publications make the lock width 80 ft. instead of 70 ft. This is an error, as, for the present at least, the 70-ft. dimension is retained. The position of lock 3, east of the divide cut, and terminating the summit level, has been moved westward to a better location, and the dam is to be of concrete, with a sluice in it. The maximum lift of locks is reduced to 40 ft. The east divide cut is widened from 80 to 100 ft. The dams and embankments of the Deseado and San Francisco basins are to be of clay instead of rock fill, and are not to be used as weirs for surplus drainage; sluices and separate weirs being proposed for that purpose.

The height and volume of the embankments has been greatly augmented and extensive excavations added for foundations in mud bottoms. The cube of the Ochoa Dam has been increased one-half, and concrete sluices have been provided for the San Carlos Ridge. The rock cut through the west divide has, like that in the east divide, been widened from 80 to 100 ft. A concrete core wall is added to the La Flor Dam and a separate waste weir provided, and the estimates for the western division locks largely increased.

As these modifications call for large additions to the quantities and cost scheduled in the detailed estimates of 1890, the company, at the request of the Board, revised the data, and the result is given in the accompanying table of estimates of date 1895. (Not reprinted.—Ed.) The total cost of the project as now estimated by the company is $66,796,800, about $1,700,000 in excess of the total of 1890.

On comparing the two schedules, it is seen that, while important enlargements of and additions to the proposed works have been made, the increase in total cost is in much less proportion by reason of reductions in the assumed unit prices and in the item for contingencies. If the quantities estimated in 1895 are computed with the same unit prices as in 1890, and the same allowance be made for contingencies, the cost of the revised project will be $78,427,534 instead of $66,796,800, an increase of $11,630,000. The matter of unit prices has been carefully considered by the Board in the light of all the information that could be obtained, and its table of estimates indicates the result, the matter being more fully discussed elsewhere in this report.

It must be noted, however, that the company has made no final detail or construction drawings so far as is known, and general data are relied upon for computing cost; the only specifications drafted are those for the dredging work and the particulars as to this are in some cases lacking in definiteness.

The Board does not believe that in the circumstances affecting the cost of work in Nicaragua, climate, rainfall, enforced importation of labor and material, absence of local mechanical and other facilities, etc., and with the experience gained in similar work at Panama and in Costa Rica, the unit prices adopted as the basis for computation could be safely reduced.

The several portions of the canal project will be discussed in detail under separate heads, beginning at Greytown and proceeding westward. For convenience, three general designations will be used:

(1) The eastern division, from the Caribbean to the San Juan River at Ochoa.

(2) The lake and river division, from the Ochoa Dam to the west shore of the lake.

(3) The western division, from the lake to the Pacific.

REGULATION OF SUMMIT LEVEL.

In the project of the company the lake is to be maintained at a minimum elevation of 110 ft. above mean tide by means of the Ochoa Dam and the embankments in the San Carlos Ridge and along the line between Ochoa and the east divide. After the construction of these works it is expected that the river at extreme low stage will have a fall of 4 ft. from the lake to the Ochoa Dam, a distance of 69 miles, giving a minimum elevation of water surface at the dam of 106 ft. The heights of the dams, embankments and regulating weirs are determined with reference to this elevation. In the report of 1890 the discharge from Lake Nicaragua at its lowest stage is said to be 11,390 cu. ft. per second, and Colonel Childs is quoted as authority for an estimate of high-water discharge of 18,059 cu. ft. per second. With these data a calculation is made, using the numerical mean of the two results to show that there will be a much larger water supply than required for canal purposes. Both the data and the method employed in this calculation are incorrect.

All the gagings of the San Juan River of which the Board has been able to find record are a series of gagings made at different points along the river by Colonel Childs in 1851; of a similar series made by Commander Lull in 1873; of a single gaging made by the canal company in 1888, and of two gagings made by the Board in 1895.

All the measurements of the discharge of Lake Nicaragua have been made at low stage, but none at the lowest. The gagings of Lull and Childs at this point agree as nearly as can be expected of gagings made hurriedly and at such a long interval of time. The stage of the lake at the time of Lull's gaging, 102.28 ft. above mean tide, has been erroneously accepted by the company as extreme low water. At the time the gaging at Fort San Carlos was made by the Board, May 26, 1895, the stage was 101.8 ft., and the measured discharge 9,420 cu. ft. per second, which accords very well with the results of Childs and Lull. A lower stage than this, however, has been of record more than 20 years. On the 2d of May, 1872, according to Lull's profile, the lake was 100.87 ft. above mean tide. Still lower stages have been reported; the officers of the "Victoria," a steamboat plying on Lake Nicaragua, showed to the engineers of the canal company a low-water mark whose elevation was 98.6 ft.; this was confirmed by residents at the head of Tisma Lagoon, near the mouth of the Tipitapa River, at the head of Lake Nicaragua, who pointed out a ledge of rock extending across the river which has been bare; its elevation is 98.5 ft. The very lowest stage known, observed at Granada, on the west side of the lake, is reported by Mr. Wm. Climie, an English civil engineer, who has resided in Nicaragua for many years. Mr. Climie reports a stage of 96.6 ft. above mean tide. This report, coming from a trained civil engineer, is entitled to great weight.

No measurement was made of the discharge of the lake at any of these low stages, but calculations indicate a discharge of 5,800 cu. ft. per second at the stage reported by the officers of the "Victoria" (98.6 ft.), and 3,400 cu. ft. per second at the lowest stage reported (96.6 ft.).

These data as to low water discharge are not, however, sufficient for the solution of the problem of the maintenance of lake level. For this purpose the lake must be treated as a reservoir. If the inflow during the dry season is less than the amount lost by evaporation, plus the amount required for canal purposes, water must be stored on the approach of the dry season and the surface of the lake raised above the established minimum stage. There is hardly any definite information as to the amount of water received by the lake during the dry season. Lull's gagings, made at several points on the San Juan in 1873, when the river was at low stage, showed that the tributary streams added little to its volume.

From the Atlantic coast, where in ordinary years there is no dry season, to the Pacific, where in ordinary years very little rain falls for five months, there is a more or less gradual reduction as regards rainfall, varied by the presence of heavily forested districts and ranges of hills and mountains. The mean annual rainfall at Greytown for three years (1889, 1891 and 1892) was 237 ins.; at Rivas, between Lake Nicaragua and the Pacific, the mean for the same years was 50 ins. No rainfall observations have been made between Rivas and the east divide, except for periods of a few days, and the rainfall on the eastern watershed of the lake is not known. There is, however, a dry season, although shorter than on the west side. It may be assumed, although with much uncertainty, that on the east side of the lake the dry season continues for four months. For a considerable time after the beginning of the dry season the streams continue to flow, their discharge becoming less and possibly ceasing altogether. For the present purpose it is assumed that during a period of two months the streams are dry, the lake receiving no water whatever. In order to make an estimate of the amount of water to be stored before the opening of the dry season account must be taken of the evaporation and requirements for lockages and leakages.

The rate of evaporation in the dry season on the Isthmus of Tehuantepec was ascertained by Capt. Shufeldt to be 0.19 in. per day. On the Isthmus of Darien it was found by Commander Selfridge to be 0.20 in. per day. The latter rate will be adopted here for Nicaragua. For calculating the amount required for lockages it is assumed, as in the company's estimate, that the maximum traffic through the canal will be 32 vessels per day. If all were moving in one direction each would require two lockfuls, less the submerged volume of the vessel; if moving alternately in opposite directions each would require one lockful, less the submerged volume of the vessel. The mean may be taken neglecting the volume of the vessel, or one and one-half lockfuls for each; then, the maximum lift of the lock on the Atlantic side being 40 ft. and on the Pacific side 47½ ft., and the lock chamber being 650 ft. long and 80 ft. wide, there will be required per day 102,960,000 cu. ft. This amount, divided by the area of the summit level, in square feet, will give the daily lowering of the summit level in consequence of lockages.

The area of the lake is taken at 2,700 sq. miles; the area of the San Juan between the lake and the Ochoa Dam, plus the area of the smaller valleys and basins submerged, will be about 110 sq. miles, making the total area of the summit level 2,810 sq. miles, equal to 78,338,304,000 sq. ft. The summit level will then be lowered each day by drawing off water for lockages 0.0157 in. The leakage at the locks and sluices may be as much more.

There will be a considerable leakage through the Ochoa Dam and through the 7¼ miles of embankment. The amount can only be conjectured, but for this estimate will be taken as 5,000 cu. ft. per second, or 432,000,000 cu. ft. per day. This will lower the summit level each day 0.0661 in.

Collecting these result the lake will be lowered—

	In. per day.
By evaporation	0.20
By lockages	.0157
By leakage at locks and sluices	.0157
By leakages at Ochoa Dam and the embankments	.0661
Total for one day	.2975

Or a total for sixty days of 17.85 ins., equal to 1.49 ft., say 1.5 ft.

This is the amount the lake would be lowered in 60 days, with no inflow and no discharge except requirements for canal purposes. If at the end of this period the lake is to be at 110 ft., it must be 1.5 ft. higher at the beginning, or 111.5 ft. As no allowance has been made for inflow into the lake during this period, this may be too high. On the other hand the dry season may be longer than assumed, and the estimate too low. Colonel Childs arrived at the same reduction of level during the dry season by a different line of reasoning, and the result is probably near the truth. More exact data are needed, and can be obtained readily, at little cost, in connection with other investigations recommended in this report.

The low water slope from the lake to Ochoa, after the completion of the Ochoa Dam, is assumed by the company at ¾ in. per mile, or, in round numbers, 4 ft. for the entire distance. With the water surface raised to so great a height the cross-section of the river channel will be greatly increased, and the velocity required to pass the ordinary low water flow of, say, 10,000 cu. ft. per second, will become so small that hydraulic formulas cannot be depended upon for precise calculations of slope; the slope will be so flat, however, that a large proportionate error is of no importance. Calculations indicate that at extreme low water the total fall from the lake to Ochoa will not be more than 0.2 ft., and probably considerably less; the river becomes really an arm of the lake and with the same elevation. Since the lake is to be maintained at a minimum elevation of 110 ft., and since, in order to secure this, the outflow must be checked on the approach of the dry season, when the lake is 1.5 ft. higher (approximately), the weirs on the San Carlos Ridge must be so arranged that their crests can be raised to 111.5 ft. or more.

The elevation of water surface against the dam at low stages of the lake being 110 instead of 106 ft., the difference will cause a notable increase in the volume of the embankments and in the lift of the chain of locks between the Caribbean and the summit level. The control of the discharge of the surplus water is a matter of no less importance than the maintenance of the summit level, but the data necessary for its intelligent consideration are almost wholly wanting. The amount of water to be dealt with, either during the year or during high floods, is unknown. The annual rainfall is not known at any point between Ochoa and the west shore of the lake. The subject is so vital, however, that an attempt must be made to cast a little light upon it with such data as can be had, and an estimate will be made first of the annual discharge.

The area of the drainage basin of Lake Nicaragua is taken at 8,700 sq. miles; of the lake itself, 2,700 sq. miles; of the drainage basin of the San Juan above Ochoa, 2,250 sq. miles. The annual rainfall in the lake basin is taken at 80 ins.; run off, 40%; evaporation from the surface of the lake, 40 ins. per year. In the river basin the annual rainfall is taken at 150 ins.; run off 60%. These figures, which may all be considerably in error, give the following results and averages in cu. ft.:

Basin.	—Received by lake and river.— Per year. (1=1,000,000)	Per second.	—Loss by evaporation.— Per year. (1=1,000,000)	Per second.	—Discharge.— Per year. (1=1,000,000)	Per second.
Lake Nicaragua	947,863	30,057	250,905	7,967	696,960	22,100
San Juan Riv., bet. the Lake and Ochoa.	470,448	14,918	Neglected.	....	470,448	14,918
Discharge at Ochoa	.....	.....	.....	.....	1,167,408	37,018

The river has never been gaged at a flood stage. A gaging was made by the company May 21-25, 1888, in the vicinity of Ochoa, but it is not known precisely where, and the water surface was not referred to the company's bench marks. The highest recorded stage at Ochoa occurred Jan. 7, 1888, and its height was noted. If the difference of stage at Ochoa at this date and at the date of the gagings were known, a rough approximation could be made to the flood discharge by a comparison of cross sections. From Dec., 1887, to Jan., 1890, the company kept a river gage record at San Francisco Island, 12 miles below Ochoa, and if this were available an indirect and approximate comparison could be made between the two stages and the flood discharge deduced. Unfortunately the record for the first seven months, including the highest stage and lowest stage observed, is missing. By other data, however, the Board has been able to establish a comparison, which leads to the conclusion that the flood discharge Jan. 7, 1888, was about 125,000 cu. ft. per second. The company's gaging, which, it is stated in the Chicago paper, established 42,000 cu. ft. per second as "high flood," represents in fact only a moderate flood; probably not much greater than the mean discharge.

During the inspection of the river by the Board in May and June, 1895, it was learned that at Machuca Rapids the flood of Nov., 1893, rose considerably above that of 1888. While it may be that the San Carlos was not correspondingly high, it does indicate that the highest flood may be considerably greater than that of 1888, and the Board is of the opinion that until more reliable data are obtained the maximum discharge at Ochoa should not be estimated at less than 150,000 cu. ft. per second.

Such a flood could only result from heavy rains over the entire river basin, in conjunction with a high lake. The extreme floods are of short duration, but a moderately high stage may be maintained for a considerable time. Sluices, or weirs with adjustable crests, must be provided in the San Carlos embankment line for the quick discharge of these floods. More precise data as to the extent of the floods are necessary before the dimensions of the weirs or sluices can be fixed, but for the purpose of entering the item in the estimates the Board has assumed weirs with a crest length of 4,000 ft. A weir of this length with a head of water of 4.5 ft. will discharge 130,000 cu. ft. per second, and this provision may possibly suffice.

Whatever the crest length of weirs may be, provision can be made for drawing off such amount of water as may be necessary by placing movable dams on them. The water on the upstream side can be kept at any desired height. Thus the discharge of the surplus water at the weir can be regulated, but the regulation of the lake itself offers difficulties, and the matter is so important and has been so completely overlooked that considerable attention must be given to it here.

During the visit of the Board to Nicaragua high-water marks were shown on both sides of the lake which fix its high stage at 111 ft. above mean tide. The variation in the surface of the lake from ordinary low water, which may be taken at 102, to high water at 111, is 9 ft. No such variation can be permitted with the lake maintained at the summit level elevation of 110 ft. as a minimum, because much valuable property on the west side of the lake would be drowned out, and for this reason it is probable that a higher stage than 113 ft. will be inadmissible. This permits an extreme range of only 3 ft., and it may be doubted whether the regulation of the lake level within so narrow a limit is possible.

During the rainy season the water is received into the lake more rapidly than it runs off, the surplus being stored in the lake, causing it to rise. The only way by which an equal rise can be prevented after the construction of the Ochoa Dam is by increasing the discharge through the San Juan during the rainy season. An increase in discharge can only be produced by an increase in cross section or an increase in velocity in the outlet channel. The water of the lake must be carried off more rapidly during the wet season after the construction of the dam than under present conditions. The increase in discharge must be very large, and it must be determined whether under the new conditions the capacity of the outlet channel will be sufficient to meet the greater demand upon it.

The data required for a solution of this problem are the amount of water received by the lake and the capacity of the outlet. The following assumed data are believed to be conservative. The area of Lake Managua and its watershed are not included for the reason that periods of several years have been known during which there was no visible outflow from that lake. It is possible that during very rainy seasons the amount contributed by Lake Managua may be considerable, and it may be that subterranean channels exist through which the lake discharges constantly:

Area of Lake Nicaragua, 2,700 sq. miles, approximately.

Area of watershed, 8,700 sq. miles, including lake. This may be considerably in error, but is taken from the best maps available.

Rainfall, 80 ins. per year. It will be assumed that 25% may fall in one month, 45% in two months, 60% in three months, and 70% in four months.

Run off, 50% of rainfall.

With these data the amount received by the lake in different periods is calculated, and also the net rise in the lake, with various rates of discharge.

Amount of water received into lake:

	Cubic feet.
In 1 month, with 25% of annual rainfall	264,844,800,000
" 2 months, " 45% " " "	476,720,640,000
" 3 " " 60% " " "	635,627,520,000
" 4 " " 70% " " "	741,560,440,000

The rise in the lake is retarded more or less by the discharge through the San Juan. The following table gives the net rise, with several rates of discharge:

	—Rise of lake with discharge of— 25,000 cu. ft. per sec. Feet.	50,000 cu. ft. per sec. Feet.	75,000 cu. ft. per sec. Feet.
In 1 month	+2.7	+1.8	+1.0
" 2 months	+4.6	+2.9	+1.2
" 3 "	+5.9	+3.3	+0.7
" 4 "	+6.4	+3.0	—0.5

It appears from the table that if the assumed data are correct, the lake can be controlled within the required limit of 3 ft. with a discharge of a little over 50,000 cu. ft. per second. The actual discharge from the lake at the highest stage, under present conditions, has not been supposed to be anything like this.

If a greater discharge than the present maximum is to be obtained, it must be produced, as before stated, by an increase in cross section or an increase in velocity in the outlet channel. Within the limits of the present case the velocity cannot be materially increased without an increase in slope. This can not be obtained without a large and costly deepening of the river bed in the vicinity of Toro Rapids, so that the question of increased discharge practically narrows down to that of increased cross section.

The height of the lake, when this average discharge of 50,000 cu. ft. per second is to be maintained, will vary from 110 ft., the minimum, to 113 ft., the assumed maximum; the average will not be far from 112, or only 1 ft. above the highest stage now known, so that no great increase of cross section will be produced by the additional height under the new conditions. Another increase, somewhat greater in amount, will result from the excavation to be made from the lake to Toro Rapids for a 30-ft. navigation.

It may be that the discharge of the lake at high water is much greater than has been supposed, and it may possibly approach nearly the amount of 50,000 cu. ft. per second calculated as necessary under the new conditions.

The governing stretch of river, as regards the outflow of the lake, is between the lake and the foot of Toro Rapids, but, affected in some degree by the natural weirs at Castillo. Below the latter point the section of the river will be so much greater after the construction of the Ochoa Dam that its capacity will be ample, with very small slopes, for the largest discharge.

If the variation of the level of the lake can not be limited to 3 ft., and if it is inadmissible to raise it above 113 ft., then it is impossible to maintain it at a minimum of 110 ft. Every foot of reduction in the minimum will cause a large increase in excavation throughout the entire summit level, including the costly work in the San Juan River and the east and west divides. The calculations just made suggest much uncertainty about this, but they are based wholly on assumptions as to the discharge of lake and rainfall, which may be far from the truth; the ascertainment of the facts by continuous observations for not less than one year and including at least one high stage of the river, is absolutely indispensable. A single year's record might prove misleading if the high stage were of unusually short duration, since it is the total quantity of discharge that is required. It is to be regretted that the canal company has no recorded observations of the lake level or other data relating to its regulation for the eight years since it began work in the country. The matter is of such vital importance that observations ought to have been made continuously during the entire period.

The discharge of the San Juan must be regulated by weirs or sluices in the San Carlos embankment; that from each minor basin (the Florida Lagoon, San Francisco Basin, etc.), by its own sluice or weir, the water level in the minor basins being made to conform to that in the San Juan immediately above the Ochoa Dam, so as to avoid currents through the narrow connecting channels.

The data do not exist for determining the discharge for which the weirs in the San Carlos Ridge should be proportioned, or for calculating the fall from the lake to the weirs during the high-water season, which must be taken into account in fixing the elevation of their crests. It is probable that in order to secure the requisite velocity through the governing section, the water surface at the San Carlos weirs must be drawn down during the wet season much below the level required during the dry season. It is essential to determine exactly how much this enforced reduction of level must be before the grade of canal bottom can be fixed between the San Juan River and the summit lock at the east divide or in the excavated channel in the San Juan itself.

The whole problem of the regulation of the summit level, the establishment of grades in the various excavations and structures within its limits, and even the practicability of the company project without much modification requires the collection of a large amount of information before it can be solved. The scope of the investigations necessary is treated more fully elsewhere.

EASTERN DIVISION.

Greytown Harbor.

The San Juan River, draining a total area of some 15,000 sq. miles, most of which in times past has been subject to intense volcanic action, and is still affected by the heavy rainfall of that region, has brought down in course of time an enormous volume of sand, in part directly emitted by volcanoes, and in part derived from the distintegration of igneous rocks and washings from the clay, and has built up in the Carribean Sea a flat and swampy delta of great extent, heavily forested and containing many lagoons and tortuous channels of varying dimensions.

The main river forks about 18 miles from the coast, and discharges through several channels, of which the Colorado is the principal, and the second in size the Lower San Juan, which reaches the sea at Greytown in the angle where the fan-like projection of the delta meets the coast line stretching to the northwest. The earlier maps show the bight at Greytown as a capacious harbor, protected from northeast winds by the delta projection, and with ample depth and area. It is now a lagoon shut off from the sea, and has ceased to exist as a harbor for seagoing vessels. The gradual closing of the harbor, between 1832 and 1862, by the movement of the outer beach stretching westward across the entrance in the form of a narrow sand spit to connect with the west shore line was a serious drawback, both to the maintenance of a freight and passenger route across the Isthmus via the San Juan River and Lake Nicaragua, and to the project for the construction of a ship canal over the same line.

The report continues with an exhaustive discussion of the problems presented by Greytown Harbor. The Board considers its destruction to be due not to the sands brought down by the lower San Juan but to the delta sands which are constantly carried by the ocean currents and waves westward along the beach. The oldest chart of the harbor in 1832 shows it as a broad open roadstead with an entrance some two miles in width unobstruced by any bar, and with 30 ft. of water over its whole surface. Comparison of charts of later dates down to the present time elucidate the causes of the harbor's destruction.

Construction by the Company.

It will be remembered that a considerable amount of money was actually expended in 1892-93 in construction work. The bulk of this was spent in work at Greytown Harbor. A pier was built 937 ft. in length which by suspending the westward drift of the beach sand enabled the channel 6½ ft. in depth to be opened by the currents in the beach closing the lagoon. Dredges drawing 7 ft. light were dragged over this bar by the aid of the sea and the entrance was thus deepened by dredging to 12 or 14 ft. The report continues:

The harbor was not at any time available for other than comparatively light draft vessels, and but three or four used it. One schooner with a load of timber for the company was wrecked in trying to enter, and vessels bringing cargoes of material were partially or altogether discharged by lighters. The beach rapidly followed out the pier extension, and as soon as the end of the pier had been reached the sand poured by and at once filled up the deepened entrance.

The pier timber and piling were creosoted with 16 lbs. of wood oil per cu. ft., but this proved unavailing as a protection from the teredo, and when examined in May, 1895, the piles near the outer end were found to have been badly eaten, and many on the channel side had disappeared. Much of the timber also was badly decayed. The teredo is very active in these waters, and excessive humidity and uniform high temperature are extremely trying to wood unless housed or well painted, and its destruction when exposed is very rapid.

A considerable amount of harbor dredging has been done by the company with its own plant, supplementing the endeavor to open the entrance, provide harborage and access to the company's buildings, shops, etc., constructed 2 and 3 miles northwest of Greytown, and to begin work on the canal. The material excavated was almost entirely volcanic sand, similar to that of the beach. This sand is dark in color, rather coarse, has a specific gravity considerably less than that of ordinary sea sand, and when submerged is readily acted upon by waves and currents. When piled in heaps it forms a porous mass through which the torrential rainfalls descend with surprisingly little effect upon its contour, even though the slopes be steep. This feature was noted both in the mounds of dredgings near the entrance and in the canal banks, where the sands dropped from the dredge chutes still stood seemingly undisturbed since they were put there.

The portion of canal work done by the company consisted of a single cut with an elevator dredge for a distance of 4,350 ft., with a width of 167 ft. and a depth of 16½ ft., followed by an adjoining cut for about half the distance. The width of the two cuts was 279 ft. The excavation was mainly within a funnel-shaped area, where the canal section proper widens into the harbor. The dredgings were left, as deposited from the spout, immediately upon the edge of the excavation, and would require rehandling to place them at a proper distance from the banks.

The total amount of dredging in canal and harbor, as stated by the company, was 727,861 cu. yds., and the total cost $80,000 in round numbers, or at the rate of 11 cts. per cu. yd., which represents the net cost of dredging in very favorable conditions, and with the company's plant, without charges due to first cost and maintenance.

The buildings erected by the company along the beach are on a liberal scale, of good design and construction, and consist of storehouses, barracks, and headquarters buildings, quarters for officers, hospitals, shops, etc. All are of wood imported from the United States, and in fair preservation, although in a state of comparative neglect, where if needed repairs, painting, etc., are not speedily attended to the buildings will be seriously damaged. In several cases the roofs are of galvanized iron, which is also used for many of the buildings in Greytown. This material shows remarkable durability under exposure to the local climatic conditions.

A large amount of property of various kinds lay out of doors and in an advanced condition of decay—numerous steel boats and launches, hulls and machinery rusted through; a pile of 8-in. spiral riveted pipe, intended to bring water from a reservoir to the barracks and quarters; spare shears for the dredges; two or three tugs and small steamboats, past all service; several scows and lighters rotten and sunk. The five dredges bought by the company from the Panama Canal dredging contractor lay in the harbor on the bottom uncared for, with rusted machinery and woodwork dropping. Three locomotives under cover are probably unserviceable. The machine shop, having been used to a certain extent by the river navigation company for occasional repairs to their vessels, was capable of service, but, with the exception of the large buildings, little else could be considered as representing any value.

In case of resumption of work at the harbor, it might be practicable to construct one serviceable dredge by building a new hull and taking out of the present dredges such machinery as would answer the purpose and be found usable. Should this prove to be practicable, the construction could be begun from inside without waiting for the opening of an entrance through the beach.

While giving a brief account of the plant and constructions at Greytown Harbor, where all the work connected with the actual canal building was done, it will be convenient to include the railway which extends inland for a distance of 11⅛ miles along the line of the canal to between the sites of Locks 1 and 2. The Board made a trip over the road on a hand car propelled with poles, and the results were of interest and value. The single track is standard gage, laid with 60-lb. steel rails, from Pittsburg, and 2,464 ties to the mile, and was built between May, 1890, and February, 1892.

The ground covered is flat and swampy for the greater part of the distance, and across the wetter portion the roadbed was formed by first cribbing roughly, then laying a temporary track and filling with sand, most of which was brought from the canal cut at Greytown. Most of this work was done by men working up to their waists in water. Notwithstanding the exposure to the immense rainfall, the roadbed when examined was found in fairly good condition, and the rails gave little evidence of corrosion, but the ties were gone. Those first laid near Greytown were of North Carolina pine, creosoted with 12 lbs. of wood oil per cu. ft., and were apparently about in the same condition as would be that of uncreosoted ties laid for three or four years in the States. Farther out, pine ties from Bluefields, not creosoted, were much decayed. The remainder, of native timber, were entirely rotten. With a few exceptions all the ties must be replaced before the road can be used.

Four and one-half miles out is a clay fill standing well with little indications of wash and leading to the bridge crossing the connection between the Benard Lagoon and the San Juanillo River. The bridge is a pile structure of ordinary type, about 125 ft. long, 4 piles to the bent, braced and capped. The noticeable peculiarity of the bridge was that it had been stayed both up and down stream with wire ropes secured to trees. Upon inquiry it was learned that the piles had been driven through 70 ft. of soft mud. As the locality in question is within a few hundred yards of the lagoon through which the canal line passes, the subsurface conditions, if continued in the lagoon, are very unfavorable features for canal building.

Beyond the bridge crossing is the first clay cut, and farther on both cuts and fills are numerous. The cuts have heights up to 20 ft., with slopes from vertical to 45°, and in most cases stood with an extraordinary stability under the tropic downpour. At several, the original tool marks were still visible, both pick and steam shovel. In several others there had been slides, but none of great extent. The ditches were generally clean, and in but few points had the wash reached the rail. The surface of the cuts was in some cases protected by vines, but in most was quite bare unless for a minute lichen.

As these clay cuts had been exposed for over three years to the severest rainfall of record on this continent, and were found in better condition on the whole than an exposure in the United States for a single winter would have left them, it is evident that the absence of frost more than balances the tropic downpour, and for the materials in question constructions can quite as safely be designed as in the United States.

A train of flat cars standing at siding was nearly covered with vines and creepers and the woodwork far advanced in decay. On the other hand, the natural growth in the roadbed was unexpectedly slight, although in two or three cases the canebrakes had invaded the track.

On the whole, taking into account the condition of the sand dumps at Greytown and of the clay cuts and fills on the line of the railroad, it is evident that the heavy rainfall is not necessarily as formidable an obstacle to outdoor constructions as might be supposed, although the slight works in question must not be too confidently accepted as safe precedents for much heavier constructions, and, with work in clay, an accumulation of water must always be guarded against.

The Board sums up its conclusions respecting Greytown Harbor with the declaration that they find the Greytown entrance adopted by the company impossible of use. They recommend that the entrance be located half-way between the Greytown entrance and the Harbor Head entrance. Here they would build two piers, one 3,000 ft., the other 5,000 ft. in length. From this entrance a straight connecting channel would be dredged 5,000 ft. long toward the deepest part of Greytown Lagoon, which would be deepened by dredging to a depth at 30 ft. over an area of 237 acres. From this basin the canal proper would begin. This change of entrance would involve the abandonment of the existing two-thirds of a mile of canal which the company has partially excavated; but this, says the Board, "is not material, in view of other and more serious considerations."

GREYTOWN HARBOR TO OCHOA.

Greytown to Lock No. 1.

The ground is a swamp nearly the whole distance; the general elevation is not more than 5 ft. above mean tide until the Bernard Lagoon is crossed, then rises gradually to 16 ft. at the foot of the hill in which Lock No. 1 is located.

The company proposes to make the bottom width in this section 120 ft., the depth to be 28.2 ft. below mean tide in Greytown Lagoon, the side slopes 3 : 1 in sand and 1½ : 1 in clay. This width is adopted with a view of constituting the section an extension of the harbor, in which vessels can lie or pass each other. The depth proposed, which is 1.8 ft. less at mean tide or nearly 2.8 ft. less at low tide than the general depth in the canal, is understood to be temporary, the full depth of 30 ft. to be obtained, after the opening of the canal for navigation, by the use of the maintenance plant. The Board believes that the estimates should cover the cost of the work completed to full depth, and that the width proposed is insufficient for passing and more than enough for the movement of single vessels. The estimates have been modified, therefore, to provide for a general width of 100 ft., with three passing places, 180 ft. wide, for a length of 600 ft., and an increase of depth to 30 ft. below low water in the Caribbean. The several changes nearly balance and involve little additional cost.

Lock No. 1 to the East Divide, 6.65 Miles.

The tide lock (No. 1) is located in a hill which projects from the north into the valley of the Deseado. It is to have a lift of 31 ft. from mean tide, raising the water surface about 15 ft. above the valley floor. A dam is required across the valley having a crest length of 1,450 ft. and a height of 23 ft. above the valley floor, or 32 ft. above the bed of the Deseado; provision is made for the regulation of the upper level by a concrete masonry sluice with two openings, each 20 by 25 ft., and two weirs of 100 ft. each, placed in depressions in the flanking hills. In addition to the above, four small embankments, of an aggregate length of 660 ft. are required in saddles between the hills to complete the line by which the upper level is to be maintained.

A canal is to be excavated the entire distance of 1.33 miles between Locks Nos. 1 and 2, with one crossing of the Deseado, which will have to be diverted. The flood discharge of the stream is not known, but is probably 3,000 or 4,000 cu. ft. or more per second. Its diversion and control will be a matter of considerable expense, for which no special provision is made in the estimates.

Lock No. 2 is located in a hill on the south side of the valley, and has a lift of 35 ft. A change to a hill on the

opposite side has been suggested, and, if made, the diversion of the Deseado above referred to would not be necessary. The same provision is made of weirs and sluices as at Lock No. 1. In addition to these, a dam and two embankments will be required to close the valley, having a total crest length of 2,030 ft.; the greatest height will be 48 ft. above the valley floor, or 69 ft. above the bed of the Deseado.

From Lock No. 2 to Lock No. 3, a distance of 4.55 miles, the line for the first 2½ miles passes through a basin formed by the dam and embankments at Lock No. 2, followed by an excavated channel for the remaining distance, in which several diversions of the Deseado, not specifically estimated for, will be required.

Lock No. 3 is located in a hill on the south side of the valley and raises the water to the summit level, which the company has assumed will be 106 ft. above mean tide, giving the lock 40 ft. lift. For reasons given elsewhere, the Board believes the level will be about 110 ft., in which case the lock will have a lift of 44 ft. There is but one opening to be closed here, the saddles in the adjacent hills being above the summit level. The company proposes to close this with a concrete dam with sluice openings similar to those at Locks Nos. 1 and 2. The crest length of the dam will be 70 ft., and the height above the bed of the Deseado will be 63 ft. No borings have been taken at this site, and it is not known whether a suitable foundation for a concrete dam can be found. A weir 200 ft. long is to be placed in the hill on the north side of the valley, and channels excavated to and from it.

A basin about 2,000 ft. long is formed immediately above Lock No. 3, affording an adequate passing place; one-fourth of a mile beyond the basin the line reaches the east end of the great cut through the east divide. The canal cross-section proposed by the company between the locks is the same as between Lock No. 1 and Greytown Harbor, viz., 120 ft. bottom width. In the opinion of the Board, navigation would be better served by reducing the width to 100 ft., and providing passing places immediately above and below each lock.

It is said, in the final report on location, of Jan. 31, 1890, that the locks are to be 650 ft. long in the chamber by 70 ft. wide. In later publications, it is stated by the company that the width is to be 80 ft. The Board has been informed recently, however, that this increase of width has not been determined on, and the company's estimates do not provide for it. The dimensions should be determined by the classes of vessels which are expected to use the canal. If it is to be adapted for the passage of the largest warships, 70 ft. will not be sufficient. The U. S. S. "Iowa," for example, has a beam of 72 ft. 3 ins., and proposals are soon to be opened for others of the same beam, while it is understood that warships of even greater beam, 75 ft., are in contemplation. For present purposes 70 ft. wide is sufficient, but the largest vessels are proving to be the most economical freight carriers, and the dimensions of the locks should be fixed with regard to the probable increase in dimensions of vessels in the near future. A future need for large locks could be met by the construction of new ones; but in any case the cost would not be increased on account of the additional width recommended more than $1,250,000 for the entire canal. In the opinion of the Board, the width of 80 ft. should be adopted, and this width is provided for in the estimates of the Board.

As before stated, the three locks from sea to summit level are to have lifts of 31, 35 and 44 ft., respectively. There is nothing necessarily impracticable in so great a lift as 44 ft., although it is without precedent. With an increase in lift the weight of the gates at the foot of the lock chamber becomes greater, but with the machinery used for the operation of locks in modern practice, there need be no difficulty in handling them. No compelling reason can be given, however, for such an extreme lift in this locality, while several reasons of much weight suggest a more moderate one. The Board proposes to substitute a system of four locks, the one nearest the sea to have a lift of 26 ft. from the level of mean tide; the remaining three, lifts of 28 ft. each. This arrangement provides structures of less weight than those proposed by the company, which is important in view of the fact that they must rest on clay foundations. The weight of gates will be less, and the time required for lockage somewhat reduced. The result will be a simplification of the system, a more conservative course as regards the dimensions and weights of the structures, a slightly increased capacity for the passage of vessels, and a reduced consumption of water from the summit level on the one hand, as against a somewhat greater first cost and cost of operation on the other.

The canal company has no detailed plans of the locks and other structures for which its estimates are made, and the Board has had to prepare preliminary drawings for the lock estimates, which take into account also a complete equipment of operating machinery, such as recent experience shows necessary; the estimate of weight of gates is based on the actual weight of the gates just built for the St. Marys Falls Canal. Data as to the cost of the operating machinery are drawn from the same source. For valuable data with reference to the construction of the new Sault Ste. Marie Lock, and for much other useful information, the Board is indebted to the late General Poe. A system of culverts for filling and discharging the locks has been provided, and also a system of steel I-beams built into the concrete floor, carrying out the idea of concrete and iron construction which has been successfully exemplified in recent arch bridges. These details, however, are used only as a means of arriving at a fairly satisfactory idea of cost.

The estimated quantities exceed those shown in the company's estimates, but are based on reliable data, and are believed to be substantially correct. It has been necessary also to increase the unit prices; for example, the price allowed by the company for concrete, $6 per cu. yd., is only about two-thirds the actual cost of concrete of similar composition used on a large scale in the locks of the Hennepin Canal, where the conditions for economical work were much more favorable than in Nicaragua in every respect, except as to the cost of cement, the saving in the latter item not being sufficient to offset the increased cost due to the adverse conditions of locality and climate. The result has been a large increase in the estimates of the cost of locks.

The borings indicate that the material to be excavated in this section will be clay. It is important, therefore, to consider its characteristics, both as regards its suitability for the foundations of structures and its probable behavior in the sides of deep cuts. A reddish-brown clay, varying somewhat in tint, is found everywhere between Lake Nicaragua and the swamps near the coast; the steep hills and the deep ravines passed over by the Board during their inspection of the canal and embankment lines showed surprisingly little scour, although in a region of rainfall several times greater than anywhere in the United States. Other observations confirmed these favorable indications.

Before the suspension of work on the canal the company built eleven miles of railway from Greytown Lagoon westward, as part of the service line to Ochoa. The western portion passed through a slightly rolling district, where several cuts, some as deep as 20 ft., with slopes from ⅛ : 1 to 1 : 1 were made in the clay hills; the tool marks left by the workmen two or three years before still showed plainly in the sides of the cuts. Although it had been raining every day for some time, the material when examined was hard and firm, and the side ditches of the roadbed were remarkably clean. From these facts the Board formed a favorable opinion of the material, which was strengthened by later observations in Costa Rica. The railway from Port Limon to San Jose has a large number of cuts in clay, several of which are over 100 ft. deep, with slopes of ½ : 1. During the visit of the Board to San Jose, a heavy rain occurred, causing a large number of land slides which stopped trains, and the Board returned to the seacoast partly by means of hand cars and partly on foot. An excellent opportunity was thus given to observe the effect of an unusually severe tropical rain on the steep clay slopes. Although the masses of clay which had fallen from the sides of the cuts were sufficient to block railway traffic, in no case were they large enough to be a serious obstruction in a canal, and a cube equal to the total amount could be removed by a dredge in a short time. The clay appeared to be quite similar to that in Nicaragua, and when it is remembered that the slope proposed by the company for clay above water is 1½ : 1 instead of ½ : 1, as in the cuts in Costa Rica, it is believed no apprehension need be entertained of serious slides.

At the sites of Locks Nos. 1 and 2 borings have been made with an earth auger, and hard clay is reported. These reports, taken in connection with the observations of the clay in the railroad cuts, lead to the opinion that the material will form a fairly satisfactory foundation for the locks, unless local variations from general characteristics should be disclosed by fuller exploration.

East Divide, 3.15 Miles.

This section consists of the continuous deep cut through the summit of the east divide. The general course of the valleys of the Deseado and Limpio is followed, but the streams are so crooked that the line is necessarily cuts through a succession of steep hills which project into the valleys from either side. The true drainage summit is crossed near the middle of the section, 17.4 miles from Greytown Harbor, at an elevation of 322 ft. above mean tide, but the deepest cutting is about one-third of a mile to the eastward, in a hill whose summit is 404 ft. above mean tide, giving a cut of 324 ft. The line is entirely in curvature, with radii of from 4,520 to 7,160 ft.

The total cube of excavation in the east divide amounts to 11,700,000 cu. yds., of which 3,400,000 is clay, and 8,300,000, or about 70% of the total, is rock. The rock is of all degrees of hardness, from decomposed teipetate to trap. The overlying material is clay, varying in depth from nothing to 115 ft., with an average of 35 ft.

The company's estimate of rock cuts are based on a cross section having vertical sides from canal bottom to 10 ft. above water, at which elevation there is a berm 5 ft. in width; above this rock is given a slope of 1 horizontal to 5 vertical; in the overlying clay the slope is 1½ : 1. The company made a series of borings along the center line of the canal at intervals of about 1,000 ft., with a diamond drill, obtaining cores of the rock passed through. These cores, arranged in order, would be a valuable record, but only a few samples from a small number of borings have been preserved. These samples, with the scanty notes turned in by the chief of the boring party, and such examination of the outcrops as the Board was able to make during the inspection of the route, constitute all the information now available.

The material called "teipetate" is found in several places directly underlying the clay, and at one point the formation was 79 ft. thick. It is a laminated clayey rock, varying much in hardness, but usually soft, disintegrating more or less rapidly on exposure to the air. At one point on the bank of the Deseado it stands nearly vertical for 20 ft., and is overlayed by a hill of clay with a steep slope; in other places the indications were less favorable, the material being much disintegrated and forming natural slopes of ½ : 1 or flatter. The conclusion seems inevitable that flatter slopes than those assumed by the company will be required at the outset, involving an increase in the original excavation, or that a heavy maintenance expense will be incurred for some time after the completion of the work.

The most serious fact shown by the borings is the existence, at great depths below the surface, of rock more or less decomposed, which may crush when the excavation is made and cause the sounder rock above to fall. The absence of good field notes and the loss of the cores are particularly unfortunate in these cases. New borings, not only on the center lines, but on the sides of the cut, in sufficient number to disclose and define the limits of dangerous materials, are indispensable, and should be made under the constant supervision of a capable engineer. The material reported as "talc" found in many places, is not properly so called, but, as far as can be judged from the samples, is a compact, solid rock. In concluding the remarks on this subject, it must be added that, so far as the information goes, there are no indications of interposed clay layers or other sliding surfaces in the rock formation. There appears to be no regular stratification, and borings in the same vicinity differ greatly in character of material passed through. The Board regrets exceedingly that it is compelled to present so inadequate a discussion of the east divide cut, the most costly section of the whole project, but the data at hand are so scanty and defective that no satisfactory treatment of the subject is possible.

East Divide to San Juan River, 12.26 Miles.

From the west end of the east divide cut the line proceeds by a tolerably direct course to a junction with the San Juan River, 1,700 ft. above the mouth of the Machado, or 2,000 ft. above the site of the Ochoa Dam, a total distance of 31.35 miles from Greytown Harbor.

The valley floors of the Chanchos, Nicholson and San Francisco rivers and the Florida Lagoon, where crossed by the canal, are about 50 ft. above mean tide, while the surface of the water is to be maintained at an elevation of 106 ft., according to the company's project, which will become 110 ft., according to the views of the Board. The valleys have considerable widths, and the Chanchos and San Francisco rivers and Florida Lagoon are crossed obliquely. These valleys are closed by a series of embankments, and the result is the formation of six basins of an aggregate length of 7.6 miles.

Much importance has been attached to these basins by the company as permitting a high rate of speed between the east divide and Ochoa. It is believed their value in this respect may easily be overrated; they are so short, the longest being only two miles and the shortest less than three-fourths of a mile, that no great increase of speed could be gained after entering one end of a basin before it would be necessary to reduce it to enter safely the narrow canal section at the other. Their principal utility, therefore, as far as the movement of vessels is concerned, is to afford passing places.

In the ridge separating the Florida Lagoon from the Machado, the company has estimated for guard gates, by which communication can be closed between the basins and the San Juan in case of a break in the long line of embankments which extend eastward from Ochoa, or if for any reason it should be desired to draw down the water in the basins. There are no drawings or plans for these gates. The canal cross-section adopted for this portion of the route has a depth of 28 ft., at the sides, deepening to 30 ft. in the middle, the bottom width being 80 ft. and the side slopes 1½ : 1. There are berms of 10 ft. on each side 10 ft. below water surface, and again 5 ft. above it. By the 2-ft. deepening at the center, the bottom sloping uniformly to the sides, where the original depth of 28 ft. is unchanged, a nominal depth of 30 ft. is obtained.

The Board inclines to the opinion that this cross-section should be deepened to 30 ft. for the full width, and widened from 80 to 100 ft., particularly in view of the square section and bilge keels of warships, but has not made any addition to the estimate to provide for this increase.

The San Francisco Embankments.

The great number of these embankments, large and small, the magnitude of some of them, and their important relation, individually and as a whole, to the construction and maintenance of the canal system as proposed by the company call for special consideration. The total distance from the west side of the east divide to where the canal line reaches the San Juan at Ochoa is 12.26 miles.

In the company's reports this distance is designated the "San Francisco division," but in this report, for convenience, it is included in the general title of the eastern division. The topography of this region is quite complicated and difficult. It may be briefly described as a suggestion of minor valleys intervening between the San Juan and the main ridge, which lies a few miles to the northward, and with their longer axes roughly parallel with the general southeasterly direction of both. These valleys drain into each other in a somewhat confused fashion, and in some cases the movement of water may be in either direction through the connecting links, but, broadly considered, discharge through the low crest of hills separating them from the San Juan by four principal outlets, viz., the Chanchos, Nicholson, San Francisco and Danta rivers, the latter draining what is known as the Florida Lagoon.

This crest line, intervening between the canal line and the San Juan, and somewhat vaguely defining the southern limits of the minor valleys, was developed after great labor by the surveying parties of the company. It loops away from the canal line at the point where the latter in its westward course from the divide leaves the valley of the Limpio and falls into that of the Chanchos, and from the common point follows a succession of steep clay hills, heavily timbered, across deep swamps and flat, muddy bottoms, intersecting the valleys of the main streams and many minor depressions with a capriciously sinuous course, which lies at varying distances of one-fourth to 2½ miles from the more direct line of the canal and joins it again in the vicinity of Ochoa. The length of the canal line between the points of junction is about 10¼ miles, while that of the crest line is 15½ miles, of which 40% is embankment.

The line of the so-called San Francisco embankments follows this crest line, and the purpose of the numerous dams and embankments is to dam the valleys of the rivers and close the other depressions, great and small, which are intercepted by it, and which it is necessary to build up to such height as to retain the surface level of the canal at the requisite elevation. The effect of this is to convert the several valleys into basins, connected by narrow passages excavated to canal cross-sections, as a portion of the canal route. The total number of embankments required for this purpose, some of them of insignificant dimensions, others of great magnitude, is no less than 67, with a total crest length of about six miles, and with heights above the ground on which they rest, varying from a few feet only to 70 ft. and upward.

As stated in the final report of 1890, the canal surface elevation being fixed at 106 ft., the dams and embankments were to be raised to elevation 112 ft., giving 6 ft. of free board; but by a recent modification, the excess of height is to be 8 ft. instead of 6, and the 1895 estimate provides for this. The largest of these individual embankments is the dam closing the San Francisco bottom and adjoining depressions, with a crest length of 1.2 miles and an extreme height of 85 ft. above the bed of the river. There are five others with dimensions approaching these, varying in length from 1,040 ft., with a greatest height of 60 ft., to 1,840 ft. in length and height of 79 ft. These stated heights are measured from the surface of the ground, and do not include depths of foundation.

With reference to this important point, the company's borings in the beds of the Danta and Nicholson sank through 30 ft. of soft mud before reaching clay, and there are two of these swamps of similar character that have not been investigated, and whose depth of mud is not known. Assuming it to be the same, there are at least four of these larger dams that will have a total height of considerably over 100 ft. above their foundation. Referring to the practical difficulties involved in the existing climatic conditions prevailing in Nicaragua, the report of 1890 has the following judicious remark:

"In a country subject to observed rainfalls of more than 6 ins. in 24 hours, the problem of drainage involves dealing with forces of nature whose enormous destructive powers are a constant menace to engineering works, however careful and skillful their design and execution."

The difficulties of construction in these conditions would have been even more strikingly illustrated by citing the observed rainfalls of 9 ins. in 9 hours and 3 ins. in a single hour. In the Chicago paper of 1893, the chief engineer says that "the series of embankments in the San Francisco Ridge, it is frankly admitted, is the weakest feature in the whole route." The report of 1890 states that—

"It is proposed to build all the embankments across the valleys in the disconnected portions of the ridge of 'rock fills' and earth backing, the crest to be 107 ft. above sea level, and with top and other slope so shaped and paved with large stones as to admit the free flow

(Continued on page 209.)

THE NEW WATER POWER DEVELOPMENT BELOW NIAGARA FALLS.

A great deal has been written during the past few years concerning the water power enterprise of the Niagara Falls Power Co. above Niagara Falls, with its long tail-race tunnel, and its 5,000-HP. turbines located in the bottom of a wheel pit at the head of the tunnel, its huge alternating dynamos, etc. Meanwhile another great water-power plant, of which the public has heard little, has been undergoing development at the

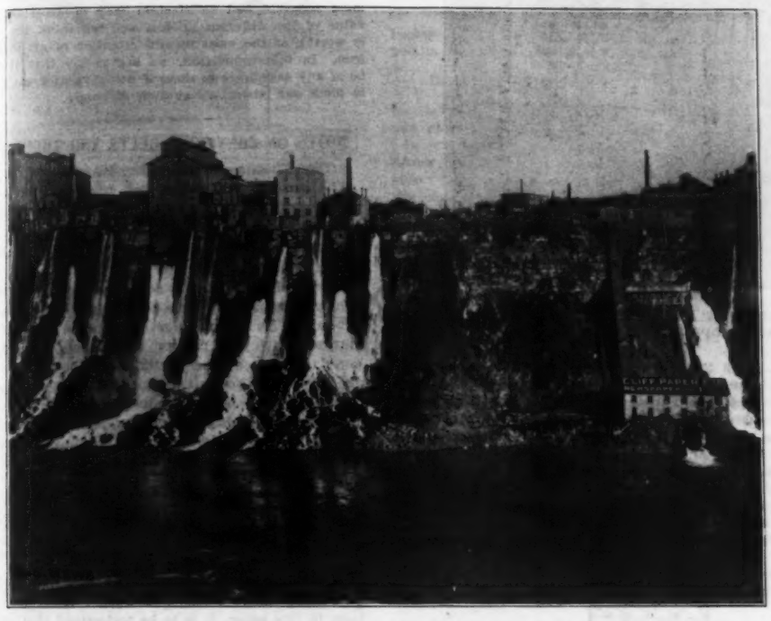


FIG. 1.—VIEW OF POWER PLANT ON THE CLIFF BELOW NIAGARA FALLS.

Fig. 4.—Hydraulic Mining of the Bank below Niagara Falls.

Falls by the Niagara Falls Hydraulic Power & Manufacturing Co. We propose here to give a brief account of some of this recent work.

Referring to the larger photograph, Fig. 1, the scene represented on the left half of the view is a familiar one to all those who have visited Niagara at any time during the past 20 years or more. The building of the Cliff Paper Co. at the right, near the edge of the river, and the flume and covered passage leading to it are only about four years old. In the view at the left the most noticeable feature to an engineer is the great waste of water due to its discharge from the various wheels at various considerable elevations above the river. The reason for this waste was due to the fact that when the mill sites were sold the power company did not own the sloping bank below the cliff, and it had the right only to excavate to a depth of 100 ft. and to discharge the water over the sloping bank. A few years ago the company acquired the lands on the slope, which enabled it to utilize the full available head of about 215 ft. This right was made use of in the construction in 1892 of the new pulp mill of the Cliff Paper Co., shown in the cut, a very complete description of which will be found in a paper by Mr. Wallace C. Johnson, M. Am. Soc. C. E., read at the Niagara Falls convention of the American Society of Civil Engineers in June, 1894. In 1892 also the company began the enlargement of its canal, which has its intake at a point about a mile above the Falls. It was originally 35 ft. wide by 8 ft. deep, and is being enlarged to 70 ft. × 14 ft., increasing its capacity, based on an available head of 210 ft., from about 13,000 to over 50,000 HP.

In the new pulp mill the water is taken from the tail race of the mill at the top of the cliff, giving a head of water, after it has already been used by the upper mill, of 125 ft. It is utilized in two 1,200-HP. double-discharge horizontal turbines, made by Jas. Leffel & Co., of Springfield, O. The wheel runners of these turbines are 66 ins. diameter, and are surrounded by wheel cylinders, each with 20 gates. The wheel, with its gates, etc., is contained in a cylindrical case 10 ft. in diameter by 4 ft. in width. Mr. Johnson's paper, above referred to, describes some of the details of these wheels, and also gives some data concerning a pulp-grinding test made with one of them, as follows: 2.085 tons of pulp were made in three hours, equal to 16.678 tons per day. The quantity of water discharged was equal to 109.-338 cu. ft. per sec. under a head of 125 ft. At this rate there is required 6.558 cu. ft. per sec. to produce one ton of pulp per day.

The photograph, Fig. 1, shows a large vacant space between the mill of the Cliff Paper Co. and the group of mills at the left. This space is now about to be utilized by the Niagara Falls Hydraulic Power & Manufacturing Co. by the erection of a large electrical power building at the bottom of the bank, by the river's edge. The plant is designed to contain ultimately turbines and dynamos capable of furnishing 50,000 HP. Three 1,700-HP. double-discharge Leffel turbines are already contracted for, and 13 more are planned for. The work is in charge of W. C. Johnson, M. Am. Soc. C. E., civil engineer of the company.

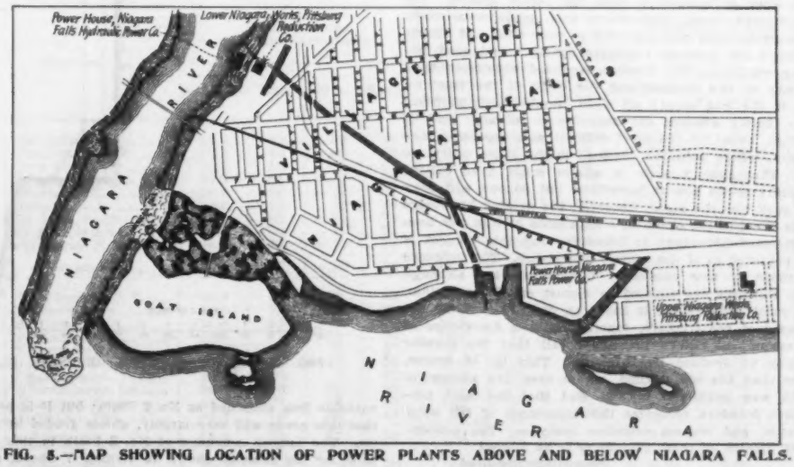

Power House, Niagara Falls Hydraulic Power Co.
Lower Niagara Works, Pittsburg Reduction Co.
NIAGARA RIVER
GOAT ISLAND
Power House, Niagara Falls Power Co.
Upper Niagara Works, Pittsburg Reduction Co.
N I A G A R A R I V E R

FIG. 3.—MAP SHOWING LOCATION OF POWER PLANTS ABOVE AND BELOW NIAGARA FALLS.

The first three turbines are to be used to furnish power to the new Lower Niagara works of the Pittsburg Reduction Co., to be located at the top of the cliff, for the production of aluminum. Each turbine will carry at each end of its horizontal shaft a 560-K-W. Westinghouse generator, or six generators in all. These will furnish a direct current of 280 volts, which is used directly in the reduction of aluminum, without transforming, the pots being arranged in series, with about 40 in each series, as the reduction requires a potential of only about seven volts.

This method of obtaining and using the current furnished by the turbine generators is very different from that used by the Pittsburg Reduction Co. at its Upper Niagara works. There the electricity is furnished originally as an alternating current of 2,200 volts. It is reduced by stationary transformers to 115 volts, and is then converted by rotary converters into 160-volt direct current, which is then used in the pots in series. The four 500-HP. rotary converters, each with a pair of stationary transformers now used at the upper works are shown in the photograph, Fig. 2. These are about to be replaced by five larger converters of 500 K-W. each. The fans shown at the right, driven by a small motor, are used for cooling the stationary transformers. All of this transforming plant is dispensed with by the direct-current system, to be used at the new lower works.

Fig. 3 is an outline sectional view showing the relative positions of the forebay, penstock and power building in the new hydraulic plant. Fig.

4 is a view of the bank being removed by a stream from a giant nozzle, as in hydraulic mining. Its operation has proved very successful. The map, Fig. 5, shows the location of the upper and lower Niagara hydraulic and power works, and their position relative to the Falls.

FIG. 2.—ELECTRIC TRANSFORMERS USED BY THE PITTSBURG REDUCTION CO. AT THE UPPER NIAGARA FALLS WORKS, NOW IN OPERATION.

ANALYSES OF PIG IRONS USED FOR DIFFERENT PURPOSES.

In the discussion of the subject of "Physics of Cast Iron" at the Pittsburg meeting of the American Institute of Mining Engineers, the following contribution was presented by Messrs. C. R. Baird & Co., of Philadelphia, in the form of a letter to Mr. Wm. R. Webster, the member of the Institute who originated the discussion:

Referring to your inquiry as to the requests of our customers for analyses of pig iron, we beg to say that until the past few years very little attention was paid to the chemical constituents, and founders generally believed that it was necessary to use No. 1 X Foundry iron for the manufacture of small castings, where softness and fluidity were essential. The quality and fitness of iron for this purpose was judged by the appearance of the fracture, and very large crystals were especially prized. An open-grained, soft iron covered their requirements. In larger machinery castings, No. 2 X Foundry was mixed with No. 1 X, or, in many cases, used alone. It was classified as "somewhat closer and harder than No. 1 X," and was not as valuable as the former, because the crystals were smaller. The next grade in price was No. 2 Plain Foundry, which was still closer in grain, and was used only for the heaviest and cheapest class of castings, or as a filler in connection with the higher grades. The light-colored, weak, high-silicon iron, made occasionally by every furnace, was regarded as poor stuff and utterly worthless for castings requiring strength and good finishing qualities. The founder depended absolutely upon the size of the crystals and the color of the fracture, and, if the iron looked all right, would, with no other guide, boldly attempt the manufacture of any kind of castings, even for the most difficult and expensive machinery, where defective castings might cause enormous loss. That such a state of affairs could have existed for years seems almost incredible, but no one will deny that such was the case. Recently, the greater knowledge of the effect of the chemical constituents of iron has been of immense advantage to founders; and this subject is now regarded as of the utmost importance. The influence of silicon is now commonly understood; but although other elements are entitled to almost equal recognition, they rarely receive it. It has been claimed that the appearance of the fracture, together with a knowledge of the amount of silicon present, is all that the founder requires to produce good results. This is, of course, better than the old method, where even the amount of silicon was unknown; but we find that the most progressive founders recognize the importance of the other elements, and request complete analyses. The concensus of opinion of these customers is as follows:

	Proportions Required.				
	I.	II.	III.	IV.	V.
Elements.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Graphitic carbon..	3.20	3.30	2.90	3.00	3.00
Combined " ..	0.30	0.20	0.40	0.30	0.30
Silicon..	2.75	3.00	2.40	2.60	2.50
Phosphorus..	0.60	0.80	0.60	0.80	0.90
Manganese..	0.60	0.50	0.60	0.50	0.30
Sulphur..	0.015	0.01	0.02	0.015	0.02

I.—No. 1 X Foundry for the manufacture of pulleys, small machinery castings, etc.

II.—No. 1 X Foundry for carrying harder pig iron or scrap, and for making choice light hardware castings, etc.

III.—No. 2 X Foundry, for heavy machinery castings, etc.

IV.—No. 2 X Foundry, for carrying harder iron, and for light machinery castings, stove-plates, etc.

V.—No. 2 Plain Foundry. There is a wide variation in the specification for this grade, which is more frequently sold without guaranty than any other. Many furnaces throw indiscriminately into the class of No. 2 Plain all iron that by fracture will not grade as No. 1 X or No. 2 X, and is too open and soft for forge purposes. By these furnace-men and by founders in general, it is regarded as an inferior iron, to be used with caution; consequently the price is low, and it is often possible to obtain very valuable iron classified as No. 2 Plain; but it is probable that this grade will vary largely, unless graded by analysis. The largest consumer of No. 2 Plain in this region calls for the analysis shown in column V above, and is able to meet his requirements at a low cost; but this is at the expense of other consumers, who do not specify analysis, and consequently get lower carbon and lower silicon, which is only the average run of No. 2 Plain iron. You, of course, realize the necessity of great variation in the specifications of the different elements in iron for widely different purposes. Where low-grade pig iron or scrap can be secured at a low price, many use a large percentage of the same in connection with iron containing as high as 12 per cent. of silicon, with most satisfactory results. Where great fluidity is especially required, regardless of strength, iron very high in phosphorus is called for, etc. Owing to the fact that we handle the output of twenty-six furnaces, which produce all descriptions of pig iron, and that we are very frequently obliged to furnish complete mixtures for various classes of castings, we have recently established our private laboratory, in charge of a competent chemist, and now make mixtures, and combine these widely different irons entirely by analysis. We gladly furnish, free of charge, a complete guaranteed analysis of not only our own brands, but of any pig iron, castings or coke that founders may send us. We find this method by far the most accurate and satisfactory way of ascertaining the value of the different grades, and we think the subject is worthy of the most careful attention of all melters of iron. In this connection, we beg to say that if we can be of any assistance to them it will give us great pleasure to place our laboratory at their disposal.

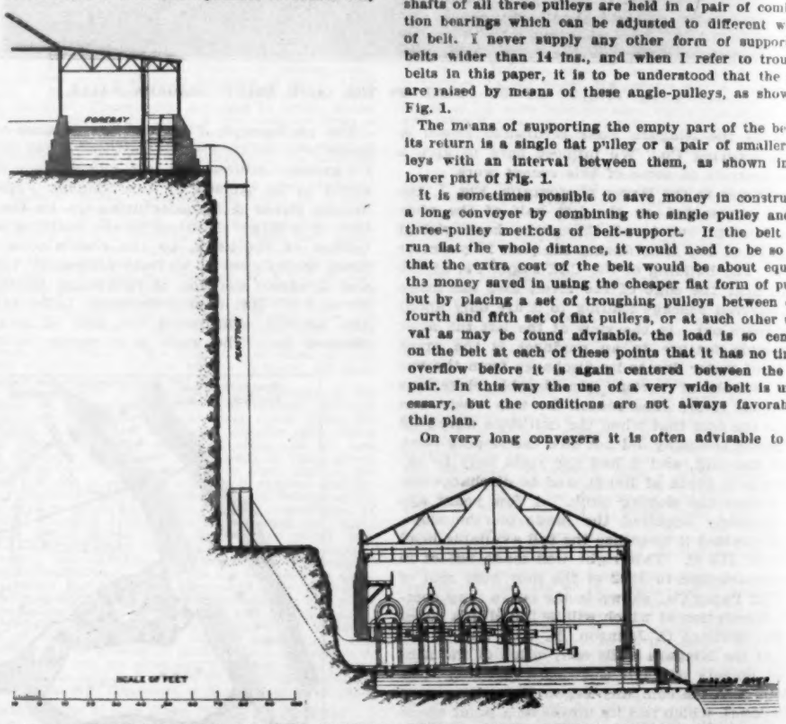


FIG. 3.—SECTIONAL VIEW OF NEW ELECTRIC POWER HOUSE BELOW NIAGARA FALLS.

NOTES ON CONVEYING BELTS AND THEIR USE.*

By Thomas Robins, Jr., New York city.

The author first describes his observations on the wear of rubber conveying belts at an iron ore-concentrating plant some years ago, which led to his experiments on the proper kind of adulterant to be added to rubber to increase its wearing power and decrease its cost, and to his patenting a belt with a reinforce of an extra thickness of rubber in its central portion. Belts made in this manner with the proper rubber compound have been in service since 1892, and are still in good order, while the belt formerly used wore out in three months. He then discusses different methods of supporting the belts, condemning plain rollers, with or without "skirt boards" at the sides, and conical side rollers. He continues as follows:

The best form of belt-support is composed of three pulleys, one carrying the middle or bottom of the belt, and one on each side with its axis at an angle of 45°. The shafts of all three pulleys are held in a pair of combination bearings which can be adjusted to different widths of belt. I never supply any other form of support for belts wider than 14 ins., and when I refer to troughed belts in this paper, it is to be understood that the sides are raised by means of these angle-pulleys, as shown in Fig. 1.

The means of supporting the empty part of the belt on its return is a single flat pulley or a pair of smaller pulleys with an interval between them, as shown in the lower part of Fig. 1.

It is sometimes possible to save money in constructing a long conveyer by combining the single pulley and the three-pulley methods of belt-support. If the belt were run flat the whole distance, it would need to be so wide that the extra cost of the belt would be about equal to the money saved in using the cheaper flat form of pulley; but by placing a set of troughing pulleys between every fourth and fifth set of flat pulleys, or at such other interval as may be found advisable, the load is so centered on the belt at each of these points that it has no time to overflow before it is again centered between the next pair. In this way the use of a very wide belt is unnecessary, but the conditions are not always favorable to this plan.

On very long conveyers it is often advisable to have about midway a pair of idlers, running on a vertical axis, or inclined inward, so as to make a right angle with the edge of the belt. These will serve to keep the belt straight on the pulleys if there is any tendency to run toward one side.

The large pulleys at the end of the belt should be slightly crowned on the face, and the pulleys should not be less than 4 ins. wider than the belt. The driving-pulley ought never to be less than 30 ins. in diameter, and in case of long wide belts 48 ins. is advisable.

*Abstract of a paper presented at the Pittsburg meeting of the American Institute of Mining Engineers, Feb. 20, 1896.

as it allows the first return pulleys to be so placed as to give the belt a very large arc of contact on the driving pulley.

Whenever it is possible it is better to have the driving-pulley at the delivering end of the belt; but, if it must be at the receiving end, a triple set of pulleys connected by gears can be easily arranged which renders slipping impossible with the longest and heaviest load.

One of the most wonderful things in connection with this subject is the exceedingly small amount of power required to move enormous quantities of material. In one case a 5-in. belt transmits all the power required to run a conveyer which carries 1,000 tons per day a distance of 180 ft., and elevates it 40 ft. while doing so.

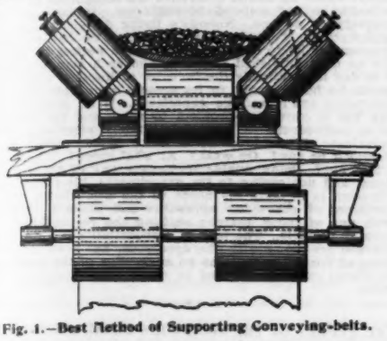


Fig. 1.—Best Method of Supporting Conveying-belts.

The entire amount of power employed does not exceed 4 HP.

I would like very much to give some rule for determining the exact number of horse-power required for conveying-belts running under different conditions, but I find it impossible, owing to the number of variable quantities which make up the load. One of the most important of these points is based upon the distance between the sets of troughing-pulleys. If they are too far apart the belt sags down between, which materially increases the load. If, on the other hand, the idlers are too near together, the extra number of bearings makes another sort of resistance to be overcome. No general rule can therefore be made by which the required horse-power can be accurately determined.

It is a simple matter to determine the necessary belt-width and speed to perform certain duty when the weight per cubic foot of the material is known. If the belt is troughed it is safe to estimate that the load itself

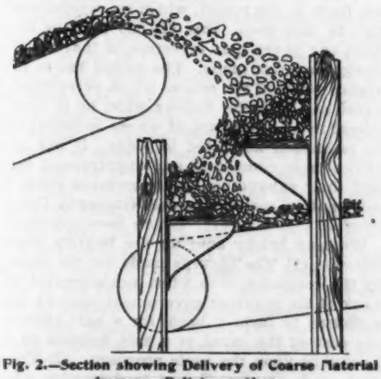


Fig. 2.—Section showing Delivery of Coarse Material from one Belt to another.

will cover one-half of the belt's total width, and that the depth in the center will be one-quarter of its own width. The area in inches of a cross-section of the load (which we may consider an inverted triangle) will when multiplied by 12 give the number of cubic inches of material borne by the belt on each running foot of its surface. Multiply this result by some estimated speed to get the quantity in cubic inches that the belt will deliver per minute, and then reduce this to the number of feet, pounds or tons delivered per hour.

For example: To find the number of tons of coal weighing 100 lbs. per cu. ft. that can be delivered by a 24-in. belt running 250 ft. per minute:

As the belt is 24 ins. wide we may safely consider the load as being a triangle standing on its apex and having a base 12 ins. wide and a height of 3 ins. Therefore the area of its cross-section will be 18 sq. ins., and there will be, $18 \times 12 = 216$ cu. ins. on each foot of the belt. As the speed is 250 ft. per minute, there will be delivered from the end of the belt 250×216 or 54,000 cu. ins. per minute. This is equal to 1,875 cu. ft. per hour, weighing 187,500 lbs., or about 93 tons per hour.

If A = width of belt, then $\frac{3A^2}{8}$ = number of cubic inches carried on each running foot of the belt. If a belt is run flat it will carry about one-third as much or $\frac{A^2}{8}$. It is well to remember that when the width of a belt is doubled it will carry four times as much material, and when it is tripled it will carry nine times as much.

In practice it is well to prepare for uneven and large pieces and for irregular feed by allowing a margin in either belt-width or speed, the two factors which govern the capacity of the belt. The widths of belting in most common use are 22, 24 and 26 ins., and the average speed is about 300 ft. per minute. I am inclined to favor higher speeds, especially for elevating at an angle, as it requires less power to lift a small sized load at a high speed than the same amount of stuff per hour in a larger sized load at a low speed. A good speed for level work is 450 ft. per minute; at an angle 650 ft. is not at all too fast; and I have seen belts working smoothly at 900 ft. per minute and at an angle of 27°. Such speed as this, however, is hard on both the belt and idlers, and I do not recommend it

Having decided upon the proper width of belting for the duty to be performed, the next points to be settled are the proper thicknesses for the belt and for its protecting cover.

The following table shows the suitable number of plies for different widths of conveying-belts:

Belts 20 inches wide and less	should be	4	ply.
" 22 and 24 wide	"	5	"
" 26 and 28 "	"	6	"
" 30 to 36 "	"	8	"

The thickness of the rubber cover should be based upon the character of the stuff to be carried. For hard material weighing over 50 lbs. per cu. ft. the cover should not be less than ¼ in. in thickness. With the patent reinforced cover, it is possible to have this thickness at the center where it is needed, allowing it to taper off to 1-16 in. or ⅛ in. at tthe sides where the work is lighter. This, of course, makes the cost lower than if the same thickness of cover extended the whole width of the belt.

At the point where a belt receives its load it gets as much wear as it meets with in all the rest of its journey. A few points should be borne in mind in connection with this part of the conveyer. The material should not be allowed to drop vertically upon the belt but should instead be so guided by an interposed chute as to strike the belt with as nearly as possible the same speed and, of course, in the same direction as that of the belt itself.

If ore or rock is carried, there is bound to be wear wherever it touches. It is well, therefore, if it has to fall any distance to let its force be broken by striking first against an accumulated pile of itself and then roll off on to a chute, whence it may slide quietly upon the belt and not move until it reaches the end of its journey. See Fig. 2, which shows the device in use at the N. J. and Penn. Concentrating Works, Edison, N. J.

The simplest method of lubricating the bearings is by means of compression grease cups which are dust proof and very economical. They are screwed into the ends of hollow shafts and a man, without stopping, can give the handles a turn as he walks along the belt, and this only has to be done once a day at most. Grease costing about 4 cts. per lb. is generally used.

Some of the purposes for which conveying-belts are used are the carrying of trap-rock and limestone in stone-crushing plants, charcoal and ashes in sugar-refineries, ore in concentrating plants and mines, earth and stone in large excavations, blocks and logs of wood in pulp-mills, clay in brick-yards, coal in breakers, yards, large power plants and culm piles, tobacco in process of manufacture, customers' packages in large retail stores, grain in elevators and flour mills, boxed goods in coffee-mills, phosphate-ore in the southern mines and chemical fertilizer in plants all over the country. These are only a part of their uses, but the list of other purposes for which, though not employed, they are equally suited, and must some day be applied, would be a very much longer one.

Records of Rainfall, in inches, at Charleston, W. Va. (on the Great Kanawha River), from 1885 to 1895, Inclusive
(From records kept at the United States Engineer's Office in that city.)

Months.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	Averages.
January	5.13	2.86	1.88	3.55	3.53	3.55	4.38	3.62	2.56	2.32	5.15	3.50
February	2.12	2.49	8 10	3.25	2.13	6.86	5.47	2.08	4.43	5.00	0 73	3.88
March	1.57	4.10	2.69	4.28	1.97	8.94	4.55	4.52	1.60	2 09	4.24	3.69
April	2.84	3.25	4.60	1.97	2.23	4.48	2 31	4 99	3.54	3.16	2.60	3.27
May	2.38	5.51	2.12	3.72	6.49	6.94	4 84	4.96	2.95	3.88	2.08	4.17
June	2.49	6.90	3.31	1.40	7.19	2.86	7.74	2.74	4.29	2.82	2 04	3.98
July	4.13	2.38	2.20	3.88	6.31	2.93	3.79	4.08	3 29	0.42	4.43	3 44
August	4.61	3.57	4.96	4.64	1 87	9.05	6.16	4.27	6 20	1.76	5.68	4.78
September	1.25	5.13	2.96	6 20	5.69	3.08	1.23	1.59	2.40	4.00	1.16	3.16
October	5.30	0.91	0.61	6.30	3.12	3.14	1.94	0.59	4.68	1.16	1.20	2 63
November	2.08	4.32	1.16	2.69	5 37	2.10	3.25	3.75	2.28	2.50	1.86	2.84
December	1.61	2.78	1.73	1.67	1.60	5.40	2.83	3.59	2.27	3.91	2.62	2.73
Totals	35.51	44.20	36.32	43.64	47.50	59.23	48.49	40.78	40.49	32.82	33.78	....
Yearly average												42.07

RAINFALL RECORDS AT CHARLESTON, W. VA.

The accompanying table shows monthly records of rainfall for eleven years at Charleston, W. Va., compiled from records kept at the U. S. Engineer's office in the city. The variation in both annual and monthly rainfall will be seen to be very considerable. It is a notable fact that the last two years have each witnessed a smaller rainfall than any other year included in the record. We are indebted to Mr. Addison M. Scott, resident engineer, for this table, which deserves careful study by any one engaged in the study of water-supply or water-power problems in the southern mountain regions.

WEATHER TABLE FOR FEBRUARY, 1896. (Furnished to Engineering News by the Department of Agriculture.)

	Stations.	Temperature. (Degrees Fahrenheit.) Average.	Max.	Min.	Range.	Wind. Velocity in miles per hour. Average.	Max.	Direction at time of max. velocity.	Precipitation—rain or melted snow—inches. Total.	Heaviest in 24 hours.	No. of rainy days.
Northern Cities.	Northfield, Vt.	15.4	42	—30	72	9.3	36	W	4.45	1.52	16
	Portland, Me.	22.4	45	—13	58	8.4	42	N	5.27	2.40	13
	New York City.	30.2	56	— 6	62	20.7	65	W	5 50	1.63	13
	Pittsburg, Pa.	32.3	65	— 2	67	9.4	36	NW	2.89	0.56	16
	Chicago, Ill.	26.6	58	— 9	67	19.9	48	W	3 48	1.52	12
	Omaha, Neb.	32.6	78	2	76	8.0	28	N	0.33	0.17	4
	St. Paul, Minn.	20 4	61	—14	75	8.9	42	NW	0.17	0.07	6
	Duluth, Minn.	16 4	54	—20	74	10.3	37	NW	0.19	0.09	7
	Bismarck, N. Dak.	16.2	58	—19	77	9.8	48	NW	0 31	0.22	6
	Average.	23.6	57	—12	70	11.6	42		2.51	0.91	10
Southern Cities.	Washington, D. C.	36.7	60	8	52	9.9	42	NW	5.31	2.29	13
	Louisville, Ky.	37.0	73	3	70	10.6	38	W	3.16	1.63	12
	St. Louis, Mo.	36 8	75	5	70	12.7	42	NW	2.81	1.77	6
	Savannah, Ga.	53.6	75	21	54	10.0	40	W	3.99	0.92	7
	Kansas City, Mo.	35.8	76	9	67	9 3	29	NW	0.82	0.58	6
	Jacksonville, Fla.	58 8	79	27	52	10.0	48	SW	1.66	0.53	8
	Chattanooga, Tenn.	43 8	70	8	62	8.6	38	W	4.84	1.26	9
	New Orleans, La.	58 4	73	37	36	10.2	32	W	2.78	1.08	8
	Memphis, Tenn.	44.8	71	18	53	11.1	38	W	3.19	0.95	8
	Palestine, Tex.	52.8	76	32	44	8.2	26	SE	7.08	2.41	10
	Average.	45.4	73	17	56	10.1	37		3 46	1.28	9
Western Cities.	Helena, Mont.	34.6	60	—3	63	10.0	48	SW	0.59	0.26	6
	Port Angeles, Wash.	42 0	57	29	28	6.4	38	SW	3.93	1.75	19
	San Francisco, Cal.	55.3	72	44	28	7.0	34	NW	0.28	0.18	5
	Salt Lake City, Utah.	36.8	60	13	47	5.2	48	NW	0.69	0.24	7
	Santa Fe, N. Mex.	33.0	57	7	50	7.4	38	NW	0.57	0.21	6
	Denver, Col.	37.8	68	9	59	9.5	54	NW	0.24	0.13	3
	Yuma, Ariz.	60.8	91	34	57	7.9	34	NW	0.00	0.00	0
	Average.	42.9	66	19	47	7.6	42		0.90	0.40	7

ENGINEERING NEWS
AND
AMERICAN RAILWAY JOURNAL.

Published every Thursday at Tribune Building, New York. Entered at the Post Office, New York, as Second Class Matter.

D. McN. STAUFFER, CHARLES WHITING BAKER.....EDITORS.
WM. KENT, E. E. R. TRATMAN, M. N. BAKER, CHAS. S. HILL, A. B. GILBERT.....ASSOCIATE EDITORS.
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GEO. H. FROST, F. P. BURT.....BUSINESS MANAGERS.
ALFRED E. KORNFELL, New York; F. A. PECKHAM, Chicago.....ADVERTISING REPRESENTATIVES.

PUBLICATION OFFICE.....Tribune Building, New York.
CHICAGO OFFICE.....1636 The Monadnock.
LONDON AGENCIES: KEGAN PAUL, TRENCH, TRUEBNER & Co. (Limited), Paternoster House, Charing Cross Road; SAMPSON LOW, MARSTON & Co., (Limited), St. Dunstan's House, Fetter Lane.

SUBSCRIPTION RATES: United States, Canada and Mexico, One Year, $5.00; 6 months, $2.50; 2 months, $1.00; Single copies, 15 cents. To all other countries in the Postal Union, add $2.08 per annum (4 cents per number) to above prices for postage. No club rates allowed. Mailing addresses may be changed at will by sending both old and new address. We shall be obliged if subscribers who fail to receive their papers promptly will notify us without delay. The number on the address label of each paper indicates when subscription expires, the last figure indicating the year and the one or two preceding figures the week of that year; for instance, the number 326 means that subscription is paid to the 32d week (that is the issue of Aug 6) of the year 1896; the change of these figures is the only receipt sent, unless by special request.

ADVERTISING RATES: 20 cents per line agate measure. Want notices, special rates, see page 22. Rates for standing advertisements sent on request. Changes of standing advertisements must be in hand on Monday (or noon; new advertisements, Tuesday afternoon; transient advertisements by Wednesday noon.

This issue of Engineering News contains 32 pages of reading matter, eight extra pages having been added on account of the space taken up by the report of the Nicaragua Canal Commission, which is reprinted in substance this week. The proprietors of Engineering News look forward to the time when its circulation and advertising patronage will warrant the publication of 32 or more pages of reading matter in an issue, not once in two or three months, as at present, but every week. There is no dearth of interesting and valuable matter to fill such additional space; in fact, the chief labor of the editors at present is to select from the large number of contributions coming to this journal that material which, on the whole, possesses the greatest practical value and interest to its readers.

Assuming that all our subscribers will welcome a permanent addition to the number of pages in Engineering News, we venture to suggest that they can do much to hasten this desired end, by taking pains to make the merits of the journal known to engineers who are not subscribers, by directing possible advertisers to its columns and by referring to the paper when corresponding with its advertisers. We are aware that many of our subscribers already take pains to aid us in these ways, and we take this opportunity to extend our thanks for these courtesies, which are none the less sincerely appreciated, although lack of time too frequently prevents their acknowledgement by letter.

In connection with the pressure upon our space, to which we have referred above, we may say a word concerning the rejection of contributions. The editors of Engineering News are always glad to receive contributions or correspondence offered for publication, descriptions, drawing, blueprints and photographs of engineering works, and all matter received is given careful examination. From it the editors select that which they conceive to be, on the whole, of greatest practical interest to the readers, and other contributions are returned to the sender, whenever it is understood that a return is desired. It should be plain enough from this that the return of a contribution by no means implies that it is lacking in originality or merit, or even that it is deficient in interest to the readers of Engineering News. The editors have to bear in mind not only the intrinsic merits of an article, but the strict limitations of space and also the needs of various classes of the readers, some of whom are especially interested in sanitary engineering, others in structural engineering, others in mechanical engineering, etc.

We hope, therefore, that our readers will continue to send us matter for publication, even though some of it may at times be returned to them. It should be plainly understood that all such matter is welcomed by the editors, as it gives us a larger field from which to make a selection; and the courtesy of the sender is appreciated even though the matter sent may be finally found unavailable for use.

During the discussion of the deficiency in the carrying capacity of the 48-in. steel water supply main of the East Jersey Water Co., it was suggested that the cause of this was largely due to not making proper allowance for the friction caused by the projecting joints and rivets. Just what difference this would make as compared with cast-iron pipe was not suggested, nor were any estimates made of the increased cost of butt joints and countersunk rivets. Evidently Messrs. Rice & Evans, engineers for water-works extension at New Bedford, Mass., and perhaps Mr. R. C. P. Coggeshall, Superintendent of the works, thought they would throw some light on one of the points. The improvements at New Bedford include a 48-in. force main of 5-16-in. riveted steel, 42,500 ft. in length. In inviting bids for this main it was specified that all proposals must include prices both for butt joints with countersunk rivets and for ordinary lap joints. The bids were received on March 19, and are published in detail in our Construction News Supplement. The specifications are identical for the two classes of work, except in the matter of the circular joints. The specified lap for ordinary joints was 2 7-16 ins., with single riveting, and the width of the straps was 5½ ins., the thickness of the straps being the same as the pipe. The number of rivets at the circular joints would be exactly doubled, and the amount of joint metal practically so, for the butt joints, to which is to be added the cost of countersinking the rivets for both the circular and longitudinal joints. The specifications provided that the countersunk rivets should not extend more than ⅛ in. into the pipe, and that the plates should make up into not less than 6-ft. lengths. The extra cost per foot, as shown by the bids, of the butt joint over the ordinary pipe, not including excavation and backfilling, ranged from 7 to 18 per cent. The lowest bidder asked $5.10 for lap-jointed and $5.65 for butt-jointed pipe, an excess of 11 per cent. for the latter. Taking the other parts of the work into account, the excess on the completed job would be only about 7 per cent. The butt joints would allow the use of smaller pipe; just how much smaller is not known, but probably it would so reduce the cost of the main as to more than offset the extra cost of the butt joints and countersunk rivets. The cost of trenching, backfilling, sheeting and other work made up about one-third of the total of the lowest bid, leaving the two-thirds of the cost of the work most affected by diminution in the size of the main.

When an efficient engineering device has been designed, built, put into use and proved to be of value, the extent of its general introduction is apt to depend not so much upon its actual merit as upon the energy with which it is advertised. In many cases it fails to become well advertised because it is not protected by patents, and therefore no one has sufficient inducement to spend money in pushing it, because much of the results of his energy and expenditure is apt to accrue to other manufacturers who begin to make the article only after it has become well known. A case in point is that of conveying belts, such as those described by Mr. Thomas Robins, Jr., in a paper of which we give an abstract in this issue. His remarks on the reason why conveyer belts have hitherto been so little used are applicable to many other things than conveyor belts, and we quote them below as a matter of general interest to engineers:

> You may say, "If this belt method of conveying is all that this man claims, why haven't we heard more about it? Why isn't it used more widely?" My answer is this: The various systems of sprocket-chain, metal-pan, trough and screw conveyers and the over-head cable system have all been owned by manufacturing concerns who make them known by advertising, undertake their construction and installation, and guarantee them. As to conveying-belts, no fundamental patent on the principle could be secured; and because a belt-conveyer is composed of two parts which are about equal in value and the products of entirely separate kinds of manufacture (I refer to, first, the iron pulleys and other supporting parts and, second, to the belt itself), no iron man felt like pushing the sale of a conveyer when he knew that some rubber manufacturer would share equally in the profits, and the rubber man would doubtless have felt the same if, with his less extensive knowledge of machinery, the thought ever occurred to him at all. And so, between them, the belt-conveyer has been neglected except where its merits compelled the recognition of a few wide-awake and self-reliant engineers. It has been the property of no one. Nobody's living depended upon its exploitation. It was to the interest of no one to stand sponsor for it: to develop, push it and perfect it. There are no data published about it, and each man who uses it to-day is practically the inventor of his own apparatus, which he has brought to its present state only after an expensive and vexatious experience. If an engineer to-day has a conveying-problem to solve and the thought of a belt occurs to him, immediately after come the questions: What kind of a belt? What width? How should it be run? On what? At what speed? Where can I find out? Being unable to answer any of these questions, and not caring to try experiments, his natural inclination is to state his needs to the well-known manufacturers of conveying apparatus and make a contract with one of them, thereby shifting the responsibility as soon as possible. The load of responsibility is apparently charged for along with the apparatus, but even the high price of the latter contains no suggestion of the great and continual expense incurred in running and keeping it in order.

THE REPORT OF THE NICARAGUA CANAL COMMISSION.

The report of the Board of Engineers appointed by the President to ascertain the feasibility of the Nicaragua Canal enterprise has at last been made public, and proves to be a document of great interest and importance. No engineering enterprise since the building of the first Pacific railway has attracted such world-wide attention. It is little more than a year ago that the U.S. Senate passed an act guaranteeing bonds of the Canal Co. to the extent of $70,000,000, in consideration of a share by the government in the control of the canal and the ownership of $70,000,000 of the company's stock. This bill did not pass the House, however, and in its place an agreement was finally reached by which $20,000 was appropriated to send a Board of Engineers to examine the canal and report upon its feasibility. In the light of the facts set forth in the report, which we reprint nearly in full in this issue, this $20,000 appears to have been one of the best investments that the United States has ever made. The nation has in this instance pursued the course which every wise capitalist and financier follows when he is invited to invest in an enterprise of whose technical details he is himself not fitted to judge. It has secured advice from competent and disinterested experts, and their exhaustive report presents much fuller information concerning the Nicaragua Canal enterprise than has ever before been available.

We may briefly sum up the Board's report as follows: (1) The surveys made for the canal line by the company, even when supplemented by the work of the previous government surveys, are insufficient to form a basis for a safe estimate of the cost of the canal or a safe decision as to its feasibility upon the route proposed. (2) The surveys made are insufficient to determine whether the route adopted by the company is the most advantageous that could be selected. (3) The Board, by supplementing existing information by assumptions made on a conservative basis, computes the cost of a canal upon substantially the route chosen by the company at 133½ million dollars, in round numbers, or about double the company's estimate of cost on which it based its appeal for government support.

It is fair to say that a part of this increase in estimates is due to the fact that the Board's estimate is for a canal 30 ft. in depth with larger locks and with a greater width and flatter slopes over a large part of the route than those proposed by the company and used in computing its estimates. Further, the Board has, as it was in duty bound to do, made its estimates conservative, and in case of doubt it has made its estimates cover the cost under the most unfavorable conditions which it considered at all probable. It may well be, therefore, that if the complete and exhaustive survey which the Board recommends were made, it would be found possible to materi-

ally reduce its figures at many points, although, on the other hand, the other contingency must be faced, that the further survey might reveal difficulties which have not yet appeared.

The report as a whole is worth careful study by every engineer interested in the Nicaragua project, and even apart from it, it possesses great value for its exhaustive discussion of some engineering problems which are of frequent occurrence. The review of the subject of rock-fill dams, for example, is by far the most complete that has ever been made.

As most of our readers will recall, the location for the canal made by Mr. Menocal and adopted by the company differs from that on which any canal has ever been anywhere built by its employment of great submerged basins, confined by lofty dams and embankments, so that the actual canal excavation is reduced to small proportions. This plan undoubtedly possesses certain great and weighty advantages over the alternative plan of a low-level canal along the San Juan valley; but the Board points out and explains in detail the bold and unprecedented character of the great works which are to confine these basins; and evidently in its opinion the risks attendant upon these are quite likely to more than offset the advantages which are claimed by their use. Concerning most of the works proposed by the company no question of feasibility is raised; the Board's criticisms are merely directed toward securing more ample and stable waterways and increasing the estimates to more certainly cover increases in quantities or safer unit prices. The greatest works which the company proposes, however, are made necessary by its choice of the high level location of Mr. Menocal on the eastern division. These are the great Ochoa dam, the deep rock cut through the eastern divide and the long line of embankments which are to confine the San Francisco basin. As to all these features the Board declares that fuller data must be collected before they can safely be approved as feasible, and a similar opinion is held respecting the upper San Juan navigation, the harbor at Brito and the great dam at La Flor; the last, indeed, is wholly discarded by the Board, and a low-level canal is recommended in place of the Tola basin, which this dam was to create.

But the question which most interests both engineers and the general public is: What is likely to be the future of the Nicaragua enterprise, in the light of this latest information concerning it?

Not much is to be hoped for it is to be feared, from the present Nicaragua Canal company. Its assets appear to consist chiefly of its concession (a property of doubtful value in view of its limitations, and the present unsettled political conditions of that country), and a mass of machinery at Greytown, most of which is already fit only for the scrap heap. The work expended on Greytown harbor and upon the short section of canal just back of it, has practically gone for nothing, according to the Board's report. For the sums expended in attempts at financial promotion, there is of course nothing to show; and its surveys, although more complete than those made for any other isthmian canal, are, in the opinion of the Board, manifestly far too meager to form a safe basis on which to found a new corporation.

We believe that no small credit is due to the public-spirited and enterprising financiers who have furnished the funds for the work thus far carried out by the Nicaragua Canal Co.; but few of them will feel like going down into their pockets again to resuscitate the enterprise in view of the present knowledge concerning it. On the other hand, there seems little reason to expect that any other group of financiers will care to take up the project, at least for some years to come. If the existing company was unable to secure public subscriptions of any amount in 1890-93, when everything appeared favorable to the enterprise, certainly a new company would stand small chance at the present day, when the Manchester canal has, justly or unjustly, given such a black eye to ship-canal enterprises generally.

But on the other hand, there is nothing whatever in the Board's report to alter the opinion of those who believe that the Nicaragua Canal will eventually be built and that when constructed it will constitute one of the most useful and beneficent engineering works of the world. The traffic that would seek a ship-canal across the Central American isthmus is generally admitted to exceed by far that which would be served by a ship-canal at any other location on the globe. Moreover, the civilized world is constantly accumulating vast stores of capital, which seeks investment on any terms, if only reasonable safety and a moderate but certain income are assured. The world is being ransacked more closely all the time in search of opportunities for profitable investment, and the enormous income which can be counted on with almost absolute certainty for a trans-isthmian canal must prove a permanent attraction to investors.

More important questions concerning the Nicaragua Canal than whether its cost will be 70 million dollars or double that sum are: What will be the risk of its total destruction by earthquake? What effect will the enormous tropical rainfall, amounting to 25 ft. in a single year, have upon its excavations and embankments? Will the Nicaraguan climate prove fatal to workmen, so as to increase the cost of the work by unknown amounts, and finally render its completion impossible after great sums have been expended? Every one of these points is fully discussed by the Board of Engineers, and on every one a distinctly favorable conclusion is reached. There appears to be no reason, then, why a safe and permanent canal should not be constructed across Nicaragua, either on Mr. Menocal's location, or on some other one if another more favorable is found. The only question is, will it pay?

On this point it may be said that the U. S. Bureau of Statistics estimated some eight years ago the traffic then existing which would seek such a canal at over 5,000,000 tons per annum; and making fair allowance for the constant growth in ocean traffic and international exchanges, 7,000,000 to 8,000,000 tons seems a conservative estimate of the traffic which would seek the canal at the earliest date on which it could now be completed. It may be noted in this connection that the Suez Canal in 1895 carried a traffic of 8,448,245 tons, on which the tolls amounted to $15,631,748. The advantage of the Nicaragua route to the traffic which would seek it is quite as great as the Suez, and although like every new transportation route, a certain time would be necessary to divert traffic from present routes, it seems a conservative estimate to assume that its annual income would amount to not less than $8,000,000 at the outset.

This would more than suffice to pay the interest on even $200,000,000, if the cost of the canal should reach such an immense sum, provided the payment of the interest were secured by a government guarantee. The prospect that the canal could be built for half that sum or less and the prospect of steady and rapid growth in its traffic and income certainly make the Nicaragua canal enterprise among the most attractive of the great engineering works of the world, far more so, for example, than any of the numerous ship canal enterprises in the United States, some of which have succeeded in attracting so much public attention.

In view of all these facts, it seems entirely clear that Congress should at once provide for the fuller surveys and investigations of the Nicaragua Canal enterprise which the Board has recommended. Even if the present or another company is later to undertake the work of construction, the United States should make these extended surveys before it grants to the company any financial aid. And if no financial aid is to be extended, then the government must, it is probable, at least make these surveys to settle the feasibility of the enterprise, as otherwise it may lie dormant for many years to come. It is to be borne in mind that such surveys, made by an independent commission of engineers, employed by the government, would have an influence upon investors that no survey made by a canal company, no matter at what expense, could possibly have.

Since the above was in type, the Nicaragua Canal bill has been reported by the House Committee on Commerce, with provisions which are given briefly in another column. It is not quite clear what is the governing object of the committee in favoring the assumption by the government at this time of the control of the canal with the guarantee of interest on $100,000,000 of bonds. It seems premature for the government to fix the capitalization and underwrite the bonds of the enterprise until data are secured by which the feasibility of the canal can be affirmed and final and accurate estimates of its cost can be made. Certainly no money should be spent on construction until these surveys are made, and there is no need of floating bonds to raise money until money is needed for actual construction.

But whatever the action of Congress upon this bill may be, it should not fail to provide for the immediate undertaking of the surveys in Nicaragua which its able expert board has recommended; and these surveys will carry more weight by far with the financial and business world if they are made directly by a government commission of engineers, than if made in the name of the Nicaragua Canal Co. Such a commission ought to include the ablest members of the profession, and to represent both its military and civil divisions. It is to be remembered that the final selection of a route must be to a considerable extent a matter of judgment; and the magnitude of the engineering problems involved in such a decision demands not only a thorough collection of all the facts involved, but the highest professional ability and experience in the men who are to weigh these facts and make the final decision upon these problems.

The wisest course for Congress to pursue, therefore, would appear to be the creation of an engineering commission to immediately undertake the surveys which the Board of Engineers has recommended.

The trivial expense which is involved in the proposed surveys is a mere bagatelle beside the prospect of benefit which the United States would derive were the canal built by any means whatever. If the matter of $350,000 is to stand in the way of these surveys being made, then by all means let us make shift to get along with one torpedo-boat less, and devote the amount thus saved to settling, once for all, the feasibility of the Nicaragua Canal and the most economical plan for its construction.

LETTERS TO THE EDITOR.

The Benefit of Sewer Underdrains at Brunswick, Ga.

Sir: It may be of interest to your readers to see the following reply from Charles S. Wylly, City Engineer of Brunswick, Ga., to my question as to the effect on the standing water, of the operation of the draining tiles laid in connection with the sewers of that city. Mr. Wylly says:

From Aug. 12 to Sept. 18 we had a continuous fall of rain, the daily average being larger than I or most people can remember. As a consequence the discharge from the 3-in. subsoil tiles increased to such an extent that I was forced temporarily to employ an assistant to the engineer in charge of the pumping station, which, for eleven days, was run continuously. In no case did any water stand in any spot within the sewerage limits longer than from three to four hours, and then only in the very lowest places. The subsoil drain works perfectly, and the worst kickers have recognized its benefit, and that it is above local criticism. All here recognize the benefit of the subsoil drainage and say for the first time Brunswick is a dry town. The practical proof is that, in making excavations for foundations or ditching, we go some 3 ft. lower before striking water.

Before Brunswick was sewered its large, almost level area was for a great part of the year saturated nearly to the surface, and all depressions were ponds for some time after each rain.

Very truly yours,
Geo. E. Waring, Jr.

Dept. of Street Cleaning, New York, March 16, 1896.

Mr. Mansergh's Report on the Toronto Water Supply.

Dear Sir: In your review of Mr. Mansergh's report on the Toronto Water-Works in your issue of March 12 you state that "Mr. Mansergh advises filtration, which none of the other engineers did in their reports." As chief engineer of the works during their construction I beg to say that the original scheme, as recommended by Messrs. Thomas C. Keefer, Past President Am. Soc. C. E. and Past President Can. Soc. C. E., and E. S. Chesbrough, M. Am. Soc. C. E., included a filtration scheme which was carried out under my direction, and which was successful when filtering the quantity which the works were designed to supply, but when double the quantity of water was required the head became so great that it forced into the basin some coloring matter and moss that was found 12 ft. below water in a 12-in.

streak, of what was probably the bottom of an ancient bed of the lake.

Nothing was done to remove this thin stratum containing organic matter, as there were so many prejudices against this basin, and so many persons had prophesied that it would fail to filter, and fail from a great variety of other causes, from none of which it did fail, that when the basin was overworked, and moss from the stratum above mentioned came in, all those who had prophesied against it, and all the many opponents of the honest administration of the water commissioners shouted "I told you so." After the works were taken over by the city council nothing further was done with reference to filtration, though the bad material might have readily been removed during the enlargement of the basin, which was necessary in order to furnish the supply demanded by the great increase in consumption.

Mr. Mansergh's report fully justifies the scheme of supply laid down by Messrs. Keefer and Chesbrough in 1872, which has been so bitterly attacked by the city council ever since, and if ordinary intelligence had been used in managing the works after they came into the hands of the city council there would never have been any trouble in maintaining a supply of good pure water.

I have not yet seen Mr. Mansergh's report in full, but I learn that he approves of the tunnel scheme. He no doubt recommended it because he supposed from the city's recent experience that a pipe could not be laid that would be tight. I am quite confident, however, from my experience with these works, that it is a very easy matter to lay a tight pipe, through the island and across the bay, between the lake and the pumping well, and to obtain by this means a full supply of pure water at a much less cost than by the tunnel scheme.

Yours truly, P. Alex. Peterson.

Montreal, March 16, 1896.

(We were aware that an infiltration basin was in use long ago. Our remark had reference to purification by means of artificially-prepared filtered beds.—Ed.)

The Future Water Supply of Greater New York.—Suggestions for a Dual Supply.

Sir: Your recent editorial on the probable water consumption of the greater New York in 1920 unfolds a rather discouraging view of immense expense and great difficulties. Would it not be much cheaper and quite practicable to provide two sources of supply and two lines of pipes: One for potable water from the Croton or other watershed, and one for industrial and fire purposes from the Hudson River.

Fully three-fourths of the water consumed in our cities is used for fire purposes, street sprinkling and washing, lawn sprinkling, hydraulic elevators, washing carriages and wagons, floors of stables and factories, washing and cooling purposes in factories, and other like purposes for which potable water is not necessary. For these requirements a separate system of pipes would be much cheaper than a distant source of supply for the whole immense demand. The present source of supply would then suffice for the demand of potable water for many years to come. Hudson River.

March 17, 1896.

(The Hudson River off Manhattan Island and for a long distance above it is too salt and too dirty to be used as a water supply, except possibly for fire protection, street sprinkling, sewer flushing, and perhaps a limited range of industrial purposes. The aggregate use of water for the public purposes named is very small compared with the total consumption, although large quantities may be used during short periods for fire protection. To duplicate street mains and service connections in a city like New York would involve a very large cash outlay, besides much interruption to traffic and inconvenience and loss to business houses. In the case of New York, the brackishness of the water might keep people from drinking it, but elsewhere the fatal objection to a dual supply is that most people drink the water that is handiest, unless it is distasteful, so that the impure supply intended for industrial purposes solely would be largely used for drinking. The great cost of duplicating a pipe system for New York and installing and operating pumping machinery would go a great way towards providing an equal amount of pure water from a gravity source, averting danger from the impure supply and obviating the necessity of tearing up the streets of a busy and crowded city.

The duplicate fire mains in use at Cleveland and one or two other places have been provided not to husband a scanty water supply, but to supplement inadequate distributing mains or to provide higher pressure, these fire mains being filled by powerful pumps located on fire boats.—Ed.)

The Diminution of Typhoid Fever in Philadelphia.

Sir: I have just read the remarks in your issue of March 19, under the heading "The Proposed Experiments on the Filtration of the Philadelphia Water Supply." While I heartily agree with you as to the necessity of filtering our water supply, and while I appreciate very highly your approval of my course in giving a reason for the faith that is in me, I must ask leave to correct a false and very injurious impression which your remarks tend to convey respecting the health of this city. I refer particularly to the following passages:

> Many a person throughout the country remembers the "Philadelphia fever," contracted by himself or some relative or friend during the Centennial. . . . Since 1876, as before, Philadelphians have suffered with typhoid, and hundreds of deaths have been caused by the disease. . . . The death roll from typhoid, caused by impure water, has reached a length that calls for a change.

While each of these statements is in itself literally and

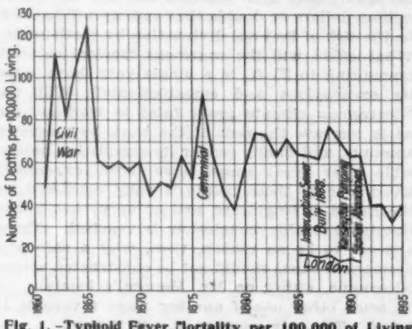

Fig. 1.—Typhoid Fever Mortality per 100,000 of Living Population, in Philadelphia, 1861 to 1895, inclusive.

strictly true, they tend, when taken together, to convey the erroneous impression that the conditions obtaining in 1876 have continued unabated, or even intensified ever since.

To show that this is far from being the case, I submit, herewith, a diagram, Fig. 1, compiled in this Bureau from the reports of our Board of Health, and showing, for each year from 1861 to 1895 inclusive, the number of typhoid deaths for each 100,000 inhabitants.

As you will see, the Centennial year of 1876, like the four years of the civil war, marked an altogether exceptional state of affairs.

In both cases our actual population was swelled by a very large influx of non-residents, who do not figure in the divisor used in obtaining the quotients plotted in the

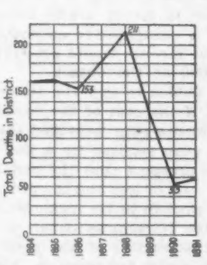

Fig. 2.—Typhoid Fever Mortality in a Section of Philadelphia Before and After Abandoning the Delaware River Pumping Station.

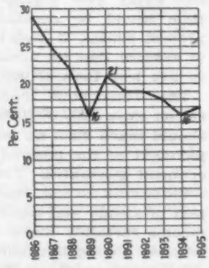

Fig. 3.—Percentage of Typhoid Cases Proving Fatal in Philadelphia from 1886 to 1895, Inclusive.

diagram. It is needless to point out that the condition of those who were thus added to our numbers during the war was highly favorable to the development of an abnormally high typhoid rate; and this was also the case, though perhaps to a less degree, during the Centennial. Our visitors, as well as our citizens, by reason of the fatigue incident to arduous sight-seeing, rendered themselves an easy prey to zymotic disease; overcrowding was the rule, even in private dwellings, to say nothing of the hundreds of hotels and boarding-houses improvised for the occasion. The summer was an exceptionally hot one, and it is alleged that, in spite of the vigilance of our health authorities, gross violations of sanitary laws occurred within the exhibition grounds themselves.

Under these circumstances it is not strange that in 1876 there were 92 typhoid deaths per 100,000 of fixed population, a very much higher number than has been reached at any time since the war, and 35 higher than the average (58) of all the years since 1865, including 1876 itself.

In the discussion upon the ordinance making an appropriation for a filter plant, it was stated, upon the floor of Councils, that the records of the Board of Health showed a continuous decrease in the typhoid death rate, and that this improvement progressed in the face of a steady deterioration in the quality of our water supply.

The diagram, Fig. 1, shows that, except in the last four years, the typhoid death rate has increased rather than diminished, the average for 1880-91 being distinctly higher than that for 1866-79, and the latter, in turn, distinctly higher than that for 1861.

During the last four years, however, the rate has been much less than at any other time during the 35 years embraced in the diagram, and these years have followed certain notable steps taken for the improvement of our water supply. I refer particularly to the completion of the intercepting sewer, in 1888, by which a very large amount of pollution was diverted from Fairmount pool, and to the final abandonment, in 1890, of the use of the old "Delaware" pumping station.

In his report for 1889, my predecessor, Mr. John L. Ogden, referring to the measures taken for the protection of the Schuylkill supply, enumerates sewers, slaughter houses, dwellings, omnibus and car stables, hotels, rolling mills, breweries, gas works, water closets, dyehouses, paper mills, an oil refinery, the House of Refuge and Girard College, all of which polluted the lowest or Fairmount pool. By the establishment of Fairmount Park and the construction of sewers, all of this filth had been removed or turned into the river below Fairmount dam, at a total cost of over $7,000,000.

The completion of this intercepting sewer, in 1888, and the final abandonment of the old Delaware pumping station, in 1890, are indicated in Fig. 1. The Delaware station was in a densely populated district and its intake drew from the river immediately below the mouth of the large Gunner's Run or Aramingo sewer. Its abandonment was marked by an immediate and notable decrease of typhoid mortality in the district supplied by it, as shown by Fig. 2, which is plotted from figures given by Dr. Henry Leffmann, of this city, in the Proceedings of the Engineers' Club of Philadelphia, for January, 1893. It may well be credited with an important share in the striking improvement shown in Fig. 1 between 1891 and 1892.*

It must be remembered, also, that while no municipal filter has been erected, the pollution of the Schuylkill water by anthracite coal dust, a feature which I find first referred to in the report of Mr. Ogden for 1888, has forced our citizens, and more particularly our keepers of hotels and restaurants, to a very general use of domestic and larger filters. It is altogether probable that, by thus forcing filtration, the "black water" of the last few years has been a blessing in disguise, improving the quality of much of the water used for drinking, and thus contributing, as might have been expected, to the lowering of the typhoid death rate.

Another cause of the improvement shown in Fig. 1 may be found in the increased ability of our physicians to deal with typhoid cases. I submit, herewith, in Fig. 3, a diagram compiled from data furnished me by Dr. Wm. H. Ford, President of our Board of Health, and showing a nearly continuous decrease in the ratio between the number of typhoid deaths and the number of typhoid cases from 1886 to 1895. The returns of cases are admittedly defective, but the ratio of defect is probably a constant quantity, and the record may therefore be safely taken as a means of comparison.

For the purpose of comparison I have drawn, upon Fig. 1, a diagram showing the numbers of deaths from "fever," including typhoid, per 100,000 persons living, in London, from 1885 to 1891, taken from the evidence of Thomas Orme Dudfield, M. D., Vice-President (and Past President) of the Society of Medical Officers of Health, and for 21 years Medical Officer of Health for Kensington, before the Royal Commission on Metropolitan Water Supply.

A comparison of this diagram with that for Philadelphia, shows that the need of filtration is sufficiently evident without any exaggeration of our city's typhoid mortality.

John C. Trautwine, Jr.,
Chief of Bureau of Water.

Department of Public Works, Philadelphia,
March 19, 1896.

(We had no idea of conveying the impression that typhoid fever in Philadelphia had been on the increase since 1876, much less continued at the same high figure. What we did wish to show was that Philadelphia has had a notoriously bad water supply for years past, and that something should be done to remedy it. Fig. 1 shows an unquestionable decrease in the number of recorded deaths from typhoid. At the same time, as Mr. Trautwine says, it is sufficient evidence of the need of filtration, or some other change, without resorting to exaggeration. But Figs. 1 and 3 together indicate plainly that the number of cases have fallen at no such rate as the number of death per 100,000 living. Taking the deaths from Fig. 1 and the percentages of

*A reference to Dr. Leffmann's paper shows that during four months of 1889 no water was pumped at the Delaware station, and that during two other months the amount was small. This will in part explain the decrease of deaths in 1889, which was greater than in 1890.—Ed.

fatal cases from Fig. 3, we may compute the total number of cases per 100,000 for each year from 1886 to 1895, inclusive, as follows:

	Per cent. fatal cases.	Deaths per 100,000 living.	Tot. cases living.
1886	29	64	221
1887	25	62	248
1888	22	78	355
1889	16	71	444
1890	21	64	305
1891	19	64	337
1892	19	40	211
1893	18	41	228
1894	16	35	206
1895	17	41	241
Averages	20	56	280

FIG. 1.—VIEW OF FOLDING GATE AT THE WALLABOUT DRAWBRIDGE; BROOKLYN, N. Y.
Augustus Smith, Builder.

It may well be that the cases are more fully reported now than ten years ago, but this still leaves room for the belief that the mortality is falling faster than the number of cases, without regard to the increased skill of the physicians.—Ed.)

THE ST. LAWRENCE WATER ROUTE TO THE SEA.

In his address as retiring President of the Canadian Society of Civil Engineers, Mr. Thomas Monro, M. I. C. E., on Jan. 15, last, briefly considered the St. Lawrence River as the great Canadian water route. He criticized the action of the Commission of 1870 in adopting dimensions of 270 × 45 × 12 ft. for the locks of the main Canadian canals. The Welland Canal was commenced in 1873 and completed on this plan in 1881, at a cost of about $14,000,000, and then $2,000,000 more was expended in deepening this to 14 ft. These locks are now too small for many of the lake vessels, and contrast badly with the U. S. lock of 515 × 80 × 16 ft., which was completed in 1880 at Sault Ste. Marie. Mr. Monro says the great cost of the Welland Canal is chiefly due to its 25 locks of only 13 ft. average lift; with 13 locks of 25 ft. lift each, a more direct line could have been selected and the first cost and subsequent maintenance would have been correspondingly decreased. The use of concrete in place of cut-stone in the fewer locks of higher lift would doubtless have enabled its builders to have constructed a canal of much larger dimensions for the $23,764,070 spent on this canal to June 30, 1895. On the St. Lawrence canals the same lock dimensions of 270 × 45 × 14 ft. are being adhered to; and to June 30, 1895, $23,109,203 had been expended upon these lower canals. The construction of the Canadian Sault Ste. Marie lock was, fortunately, not commenced until 1888-9, and the progress of events prevented the adoption of the smaller dimensions for this lock. After various changes of plan the final dimensions were fixed at 900 × 60 × 20¼ ft., and the lock is practically finished at a cost of $4,000,000, including the canal of which it forms a part.

In considering the prospects for an increased trade through the St. Lawrence to Montreal, when the canals are all deepened to 14-ft. draft, the late unparalleled reductions in freight rates on the upper lake become an important factor. Mr. Monro points out that this is largely due to the rapid increase in the individual tonnage of lake steamers; the aggregate tonnage being be built at a cost of about $8,500,000; and 42 of these new freight steamers, on 14½-ft. draft, 1,241,459 tons on June 30, 1895. In the lake shipyards, this winter, 65 vessels of all kinds will will carry an aggregate of 136,000 tons gross. With the average number of trips allowed them this addition to the fleet will carry about 2,500,000 tons of iron ore, or other heavy freight. As another consequence, grain is being carried 870 miles, from Chicago to Buffalo, at about half the rates of 1886. In the latter year the average cost was 3.6 cts. per bushel between these points; in 1894 it was 1.2 cts., and in 1895 it was 1.9 cts., and grain was carried in July, 1895, for 1 ct. per bushel. It is also important to note in this connection that work is in progress for securing a 20-ft. channel throughout the lakes, and this will surely further reduce rates.

Mr. Monro then discusses the grain business between Buffalo and New York, and says that the Erie Canal carried only 14,612,700 bushels in 1895, as compared with 42,608,700 bushels in 1894. The canal rates between Buffalo and New York varied from 3 cts. to 1⅞ cts. with an average of 2⅜ cts. But in face of these prices the railways carried twice as much grain last year as in 1894. The expenditure of the $9,000,000 canal fund, however, securing a 9-ft. depth, with electric motors and other proposed improvements, may, says Mr. Monro, again enable this canal to hold its own in competition with other routes. He places the probable average of lake rates on wheat, in the near future, at 1½ cts.; the reduced Buffalo charges at ½ ct., the improved Erie canal rate at 2 cts., and thus figures that 4 cts., as a maximum, will soon carry 60 lbs. of grain from Chicago to New York, a distance of 1,368 miles, and pay a fair profit at that. This competitive rate must be faced by Canada.

Mr. Monro says that one reason why "Western trade" does not follow the St. Lawrence is because this river does not lead to the chief market. The grain from the lake region is largely consumed in the Eastern United States, as is shown by the fact that out of 123,184,499 bushels received at New York in 1894, only about 62,000,000 bushels were exported; and it is only with this latter half that the St. Lawrence can compete. It was also assumed for years that if grain once found its way to Lake Ontario it must inevitably go to Montreal for distribution or export; but the fact is that over half the tonnage passing east through the Welland Canal goes to United States ports. It is a significant fact that the seagoing tonnage of Montreal has remained at about the same figure for several years, while the trade of Buffalo has doubled since 1886, and in 1895 was 9,612,423 tons against 1,069,386 tons for Montreal. Even with similar freight rates, says Mr. Monro, the trade will go via Buffalo to New York; because New York is the commercial metropolis of North America, the great money center. Montreal, too, is cut off from the sea by ice-bound channels for nearly half the year, while the At-

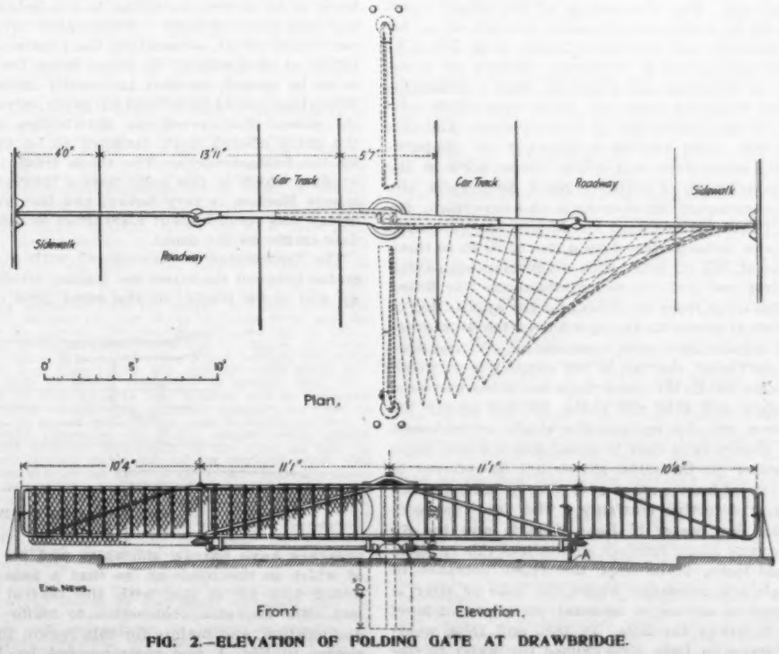

FIG. 2.—ELEVATION OF FOLDING GATE AT DRAWBRIDGE.

lantic ports of the United States are open all the year.

In connection with the Canadian canals, upon which $53,500,000 has already been expended, Mr. Monro says that as soon as a vessel of 2,000 tons can pass from Lake Superior to Montreal without breaking bulk, the present grain rate may be cut in two by using a cheaply built class of steam propellors towing a consort, each vessel to be the full size of the locks, and Montreal may then stand a chance of getting a fair share of the transatlantic trade. This requires the immediate completion of the Canadian canal system and the adaptation of the port of Montreal for the rapid transfer of cargoes to ocean steamers. Mr. Monro then makes a few practical observations on the leading principles which he believes should govern the location and construction of canals designed for the passage of large vessels.

In such canals a straight course warrants a large expenditure, as 3,500-ton vessels moving at 4 miles per hour have to be guided with the utmost care to prevent accident. When change of direction is necessary, curves of large radius should be employed. The dimensions of the canal prism should be uniformly preserved throughout, as far as possible, and mid-canal bridge piers are to be especially avoided. Concrete, instead of stone, can be efficiently and profitably used in lockwalls, weirs, retaining walls, etc., as the cost will be one-half to two-thirds that of dressed stone. And this concrete could also be substituted for comparatively short-lived and costly timberwork in the superstructure of entrance piers, dock-walls, etc. The increase of lift at locks is also important. On the Beauharnois Canal Mr. Monro has decreased the nine locks proposed for a rise of 70 ft. to three locks of 23½ ft. each, with a considerable saving in first cost and future maintenance. The filling of the locks from the sides and the application of electrical power to the opening of the lock gates and drawbridges were commended. On the Soulanges Canal, the fall in the summit level would provide 750 E. HP., and plans are being perfected to open and shut the gates, fill and empty the sluices, etc., by operating a single switchboard. Mr. Monro says that in canal location the depth of water on the miter-sill should be referred to the lowest known stage of a river or lake, and not to any defective statistics. The late unprecedented low water in Lake Ontario and the St. Lawrence River forcibly emphasizes this caution. Guard-locks, at or near the upper entrance of canals are necessary where the lake or river is subject to storms or unusual variations of level due to heavy rainfalls. In 1886 and 1889, westerly gales on Lake Erie caused the water to rise 4 ft. at Port Colborne, on the Welland Canal, 7 ft. in the aqueduct, and about 9 ft. at the guard gates at Thorold. Had a break occurred at this point the damage to the country below would have been enormous. The guard-lock at the head of the Cornwall Canal, at the time of the break of Oct. 11, 1888, converted what might have been a total stoppage of navigation for the season into an interruption of traffic, serious but comparatively short. Guard-gates are not sufficient for this purpose, for, if open, they would be useless, and if shut, as they should be, they could not be opened until the head against them had subsided.

GATE FOR THE WALLABOUT DRAWBRIDGE, BROOKLYN, N. Y.

The advisability of protecting the ends of a roadway at a drawbridge when the bridge is swung open for navigation has been shown by numerous accidents, of which the one at Cleveland on Nov. 16, 1895, was the most notable. We illustrate this week the gates now in use at each end of the drawbridge carrying Washington Ave. over the Wallabout Canal, in Brooklyn, N. Y. In November, 1894, the city advertised in our columns for competitive plans and bids for such gates for this bridge, the gates to be operated by hand or by power, according to the judgment of the respective bidders. Washington Ave. is a very busy street, demanding the presence of an officer at each side of the canal when the bridge is to be opened, so that apparently little or no advantage would be offered by gates operated by the power that moved the drawbridge, and all the gates offered were designed to be operated by the bridgetenders. The truck traffic on the avenue, which at this point passes through Wallabout Market, is very heavy, and last year the bridge was opened about 4,500 times to accommodate traffic on the canal.

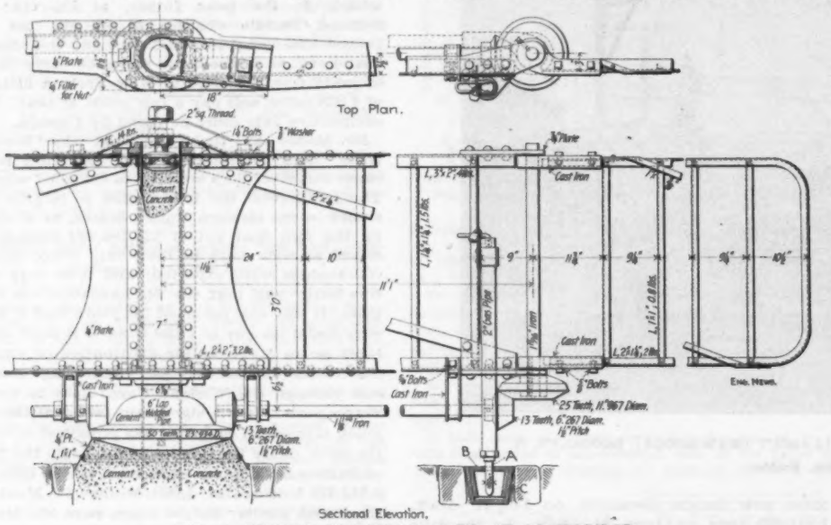

FIG. 3.—DETAILS OF FOLDING GATE AT DRAWBRIDGE.

The drawbridge is constructed with a central girder between the street car tracks, dividing the up and down traffic; at the same time the approaches have narrow sidewalks and no excess of width in the roadway, so that a gate which would fold up in line with the central girder and offer no extra obstruction to traffic was a desideratum, and mainly for this reason the gate shown in Fig. 1 was recommended by Mr. E. Sherman White, Engineer of Construction and Repair. This design was submitted by Mr. Augustus Smith, C. E., of 39 Cortlandt St., New York city, and the contract for construction was awarded to him, with the stipulation that the gates should be kept in repair for a year without expense to the city. The gates are about 20 ft. from the edge of the canal, measured on the center line of the street.

Each gate consists of a central frame, 42 ft. 2 ins. long and 3 ft. high, built up mostly of angle irons and mounted at the center on an upright post of 6-in. gas pipe set firmly in the street. At each end of the main frame is hinged a wing 10 ft. 4 ins. long by 3 ft. high, also formed of angle irons, but made as light as possible. The gate, therefore, when extended, measures 62 ft. 10 ins. from end to end. Each end wing is connected by bevel gears and a shaft running along the bottom of the main frame to a pinion traveling around a bevel gear fixed to the ground. The ratio between the ground gear and the gears fixed to the outer wings is 2 to 1, so that when the main frame is revolved 90°, or from its position between the car tracks to a position across them, the outer wings are each revolved by the motion of the central frame through an arc of 180°, or from their folded position parallel to the main frame between the car tracks to an extended continuance of it across the street.

A bolt, A, Figs. 2 and 3, is provided, which drops into a socket set in the pavement, and thus holds the main frame in position, either parallel with the tracks or across them. When the gate is folded up, the outer wings are held close in by the gearing, but when the gate is opened out across the street, the outer ends of the wings enter between two posts and set close to the sidewalk railing, so that any strain brought on the gate by the pressure of an impatient crowd or unruly truck is borne by the central post, the bolt and the sidewalk posts holding the ends of the wings, and no strain comes on the gearing.

The extreme point of each outer wing moves in and out in practically a straight line, as will be seen from Figs. 1 and 2, and as the central frame is set so as to swing away from the advancing traffic, no backing up of trucks is necessary to make room to fold the gates. The bolt is arranged so that it can be locked down, holding the gate open or shut. The socket for the bolt A is made of an inverted cast-iron box, B, with a hole for the bolt in the bottom, the box resting in an outer cast-iron box, set right, C, in the pavement. The inner box can be lifted out when the bolt is not in it, and any dirt readily removed.

The weight of the whole gate is carried on a nest of 1-in. steel balls rolling between hardened steel plates, resting on Portland cement concrete, which fills up the hollow central post. Vertical adjustment is secured by a 2-in. square-threaded screw bearing on the upper ball plate, and diagonals with a sleeve-nut adjustment are provided in the main frame and wings to prevent any sag in the gate. The central fixed gear and pinion are protected from the street dirt by a light sheet-iron box, with hand doors for greasing the gears. A wire netting reaching to the ground is fastened over the frame for additional security.

The gates are easily and quickly operated by the bridgetenders seizing the main frame at the bolt, and have received the sanction of the city authorities. They were turned over ready for use in May, 1895, and up to the present time no requisition for repairs has been found necessary. One has been tested by a runaway horse dashing against it, with the result that the horse was killed and the gate uninjured. As it is better in such cases to have the horse killed than persons in a carriage carried into the water the result may be considered as satisfactory.

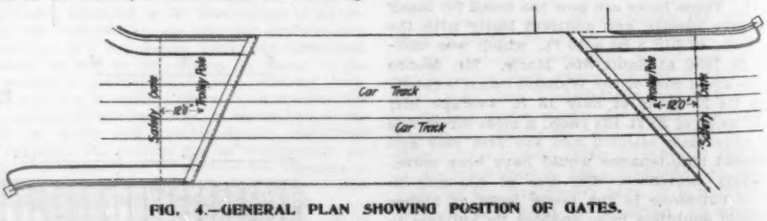

FIG. 4.—GENERAL PLAN SHOWING POSITION OF GATES.

THE REPORT OF THE NICARAGUA CANAL BOARD.

(Continued from page 200.)

of water over the surface without danger of injury, all other embankments to be 112 ft. above sea level. All these embankments will be in fact so many waste weirs for the discharge of the surplus water at several points in the basin, with an aggregate length of 4,720 ft. of spillway, and assuming that the embankments are perfectly tight, which will not be the case until several years after construction, and therefore that all the surplus water passes over the weirs, the maximum thickness of the crest will not exceed 15 ins."

It is not clear for what amount of drainage or for what area these weir arrangements were intended to provide, as the streams in question have never been gaged in flood, nor their water sheds measured.

The slopes of the rock-fill dams were to be 3 : 1 on the water side and 2½ : 1 on the dry side. It is evident that the maintenance of these rock-fill dams, sustaining a head of 60 or more feet and with a current pouring over the crests and down the rear slope, seemed doubtful, and the company later changed its plans by dispensing with rock fill and using clay exclusively. Furthermore, the height of all the dams was raised to elevation 114, 8 ft. above the canal surface. In such case the embankments are no longer to act as weirs, and the drainage is now provided for by three concrete masonry sluices, each having two openings 20 by 25 ft., placed at suitable points in hills adjacent to the main valleys of the San Francisco, Chanchos and Danta, and built at so low a level as will provide for the diversion of these streams while the dams are under construction. In addition to the sluices are three weirs at different points; one of 250 ft., one of 200 ft., and one of 150 ft., with their crests at elevation 104, or 2 ft. below the canal surface elevation 106.

The canal company has thus avoided two construction difficulties by dispensing with rock fill and the use of the dams as weirs, but has apparently repeated the error made in connection with the Ochoa Dam and the San Carlos weirs, of supposing that with an invariable width and depth of weir a uniform elevation of water surface can be maintained, with a variable afflux.

It is evident that with a fixed weir capacity, adapted to perhaps an assumed mean discharge, the water surface elevation must run down when the discharge or afflux becomes a minimum, and, on the other hand, must rise as the afflux exceeds the supposed mean. It is also evident that, in order to meet these varying conditions of afflux and still maintain a uniform surface elevation, either the sluices must be manenvered to regulate the discharge, or the weirs must be equipped with flash boards or movable dams that can be adjusted to meet the same purpose.

As elsewhere stated, the Board deems a surface elevation of 110 ft. needful, instead of 106, as the company proposes. This will call for the raising and enlarging of all the embankments, for which the necessary additions have been made in the Board's estimate. Using the same free board as that of the company, 8 ft., the elevation of embankment crest will be 118, and the height of crest above the average valley floor, assumed at elevation 46, will be 72 ft. The lowest valley floor is that of the Danta at elevation 40, where the mud is 30 ft. deep, making the height of the dam 108 ft.

The construction of these vast accumulations of clay, under the heavy rainfall, and their effective consolidation into impermeable and stable structures will call for the exercise of the utmost care and skill. The use of animals or vehicles of any kind on the fill will in all likelihood be impracticable and the deposit of the material and its consolidation in layers will probably involve the use of cables for delivering the clay in skips and hauling the rollers from side to side. As the San Francisco embankment alone has a total length of nearly 1¼ miles, the problem of its construction constitutes by itself a sufficiently formidable task.

The clay to be obtained from the west side of the divide cut and from excavations in the San Francisco basin is not sufficient for the construction of these embankments, which aggregate over 7,000,000 cu. yds., and a large quantity, computed at about 2,500,000 cu. yds., must either be borrowed from hills in the vicinity of the work or hauled from beyond the summit of the east divide. For the protection of these high banks after construction the surplus rock from the divide cut may be used to cover the slopes.

The excavations of the deep mud bottoms referred to is also a difficulty. Their widths are not known and they probably follow the line of the valleys above and below the embankment line for long distances. In order to excavate a foundation for a dam the inflow of soft mud from the two ends must be cut off, and probably the construction of crib piers filled with stone and sunk in the mud parallel with and at suitable distances from the upper and lower foot slopes of the dam, will be the cheapest and most effective means of doing this. The cost of auxiliary work of this kind is included in the unit price ($1.50 per cu. yd.) adopted by the Board for the mud excavation.

It is proper to note the multiplied points at which the canal would be exposed to injury after construction, and the comparative facility with which a breach could be made at any point on the long line of embankments, if, for any reason, military or malicious, it should be intended to destroy the canal navigation until the breach could be closed.

LAKE AND RIVER DIVISION FROM OCHOA TO WEST SIDE OF LAKE NICARAGUA.

The Ochoa Dam and the San Carlos Ridge.

The dam across the San Juan River at Ochoa, about 69 miles from the lake, is the main prop of the company's project, and, like the pier of a cantilever bridge, upholds the burden of the great constructions that stretch in both directions to constitute the waterway. The bold project of extending the summit level of the canal from the lake to Ochoa, and thence to beyond the east divide within sight of the Caribbean, depends upon the successful building and maintenance of the structure.

The dam is designed: First, to intercept the flow of the San Juan below its junction with the San Carlos and submerge the valleys of both rivers, converting them into arms of the lake. The effect of this would be to add some 2,300 square miles to the lake watershed. Second, to maintain the water surface of the flooded valleys at such an elevation as will prevent the lake from falling below its adopted minimum stage, viz., 110 ft. above sea level. Third, to prolong the summit level eastward from the dam through the San Francisco basins and the east divide cut to Lock 3 in the Deseado Valley, 17 miles from Greytown. Fourth, to act as a weir for a discharge over its crest of the surplus waters of the lake and San Juan watersheds.

The San Carlos is the principal affluent of the San Juan and drains an area of some 1,250 sq. miles, which reaches back to the lofty summits of the Costa Rican ranges, and is subject to a heavy and variable rainfall. The river, therefore, has a quick watershed, and is liable to heavy floods. It discharges into the San Juan about 65½ miles from the lake and 3½ miles above the proposed site of the Ochoa Dam.

The ridge that bounds the San Carlos Valley on the east side is too low at numerous points within ten or twelve miles from the San Juan to sustain the high-water level, and 21 embankments are needed to close the gaps and raise the crest to the requisite height. At suitable points in this ridge the company proposes to build three weirs, with an aggregate length of 1,200 ft., to aid in discharging the surplus volume of the two streams, and has recently added two sluices 20 ft. wide and 25 ft. high for the same purpose. The San Carlos Ridge is therefore a necessary adjunct, and practically a continuation of the main work.

Since the Ochoa Dam is to sustain the volume of a reservoir nearly 3,000 sq. miles in area and control the entire summit level, it will determine the elevations, magnitude, and cost of all the constructions through both the east and west divides, the great embankments in the San Francisco basins, and the extensive rock and other dredging in the San Juan and lake channels, representing about one-half of the total cost of the project.

The determination of its height and other dimensions, and the selection of the materials and methods of its construction are therefore matters of vital importance; a reduction of even a foot or two would impair navigation, and any considerable excess would endanger some of the works, while the failure of the dam would leave the navigation stranded, wreck the valley below, and possibly wash Greytown into the sea. A work of this kind, designed to control a large river, and upon which interests of such magnitude depend, can not be too thoroughly considered or too securely built. The engineer should know the conditions under which he is to work, the forces with which he has to contend, and the probable magnitude of their opposing action, if he is to plan his work wisely and insure its safety. It is important to know: First, what is the nature of the river bed and banks upon and between which the dam is to be built. Second, what are the physics of the stream itself; its range between low and high water stages; its varying slopes, velocity, and volume; the magnitude, duration and frequency of its floods. Unfortunately, information of this kind is seriously deficient.

The company's surveys are mainly devoted to topography, and did not include the collection of hydraulic data. No survey was made of the river, and but one gaging, and that of no present value, as the stage of river when it was made is not known. For information of this kind, recourse must be had to the imperfect data given in the Childs and Luil reports of 1852 and 1873, respectively, and obtained during the recent inspection of the river by the Board. The company has no detailed plans or specifications for the dam, but the following from a paper prepared by the chief engineer of the company for the Water Commerce Congress at Chicago in 1893, pages 28 et seq., gives a description:

"The Ochoa and Tola dams are the keys controlling this great problem at the east and west ends of the summit level, and should not be passed without special notice, particularly so the former, in which a novel method of construction is contemplated. This work has been for years the subject of long study and careful consideration. The diversion of the River San Juan is well-nigh impossible, and construction by the usual methods, with either cut stone or concrete, of so important a work in opposition to the mighty power of the stream is a problem involving the most serious difficulties. It was at first proposed to build a stone dam upon a series of arches supported by piers starting from the foundation, through which the river waters could flow freely during the construction of the main part of the structure, these openings to be closed by gates in the upper side when the upper part of the dam, its approaches and aprons, were completed; and then to be filled with masonry from the lower side, while the water was rising in the basin. This was, perhaps, as a practical solution, probably the best under the circumstances, for that style of dam; but its execution would be tedious, difficult, and expensive, and there was to be always present an element of doubt not easy to eliminate as to the final success. The building of the foundations and pilasters for the support of the arches in constant contention with the whole river would be a most difficult undertaking, in which the items of time and cost would remain unknown quantities to its completion. Another idea has since been suggested, which seems to embody simplicity, economy and safety. It consists in dumping from an aerial suspension conveyer large and small material properly assorted, across the river from bank to bank until a barrier is created sufficiently high and strong to arrest the flow and hold the waters at the required level, the body of the dam to be made up of large blocks of stone, weighing from 1 to 10 tons, and smaller material to fill the voids. Its base will be quite broad as compared with the height, probably from 400 to 500 ft. between the foot of the upstream slope and the end of the apron. The top is estimated 30 ft. wide, the rock upstream slope 1 to 1, and the apron, or downstream slope, 4 to 1, with the lower portion flattening down to 5 or 6 to 1. On the upstream side small material, such as stone, fragments of gravel, clay, etc., selected as circumstances may require, will be deposited as the work advances, in sufficient quantity, as tight as wanted. It is not expected or even desirable to have a water-tight structure, the object sought being simply to oppose such an obstruction to the river as may be necessary to hold the waters at the required level. The minimum flow of the river is about ten times the water needed for working the canal. Consequently, nine-tenths of it can be wasted with advantage. That the dam will eventually become tight there can be no doubt, as the small drifts and detritus forced in by the current will gradually fill the voids and consolidate the structure.

"The method of construction will be quite simple. After protecting the abutments against possible erosion, large pieces of rock will be dumped in the bed of the stream from three or four cableways spanning the valley. The material should be distributed uniformly over the area upon the main portion of the dam commencing upstream and keeping up, as nearly as possible, an even level. Scouring will soon cause settling of the blocks into firmer soil, the upper level in the meantime being constantly raised by depositing more stone, while the small material is being forced by the current into the voids, and the overflow dislodging and rearranging the unstable blocks until they reach a final resting place. This process to be continued until the resistance at the bottom becomes so great as to check scouring due to maximum pressure, when the dam will be carried up to the desired level. The river, in the meantime running over the mound, will readjust the material in and adapt the apron to the necessary conditions of stability to withstand the effect of the fall, and carry off the water safely. If the dam is then raised so as to shut off a whole or the largest part of the river flow, which can by that time be discharged over the waste weirs, the structure will be permanent. If the river is not able to prevent the completion of this work, having, on the contrary, greatly contributed to its construction by a better distribution and consolidation of the material, now that the waters are diverted to another outlet, no fear need be entertained as to injury from that source. There may be some settlement and final readjustment of the component parts for some time after completion, but that can be easily remedied by depositing more material where needed. It is believed that this dam will be safer, as it is by far more economical, than a stone dam. An earthquake might cause serious damage to a masonry dam, but it can do no harm to this. On the contrary it may add to its consolidation by bringing the parts in closer contact. There are no cemented joints to be opened, and a seismic disturbance would have a tendency to compact rather than to disintegrate the large mass. The rock for the dam will be brought by rail from the divide, and delivered immediately under the wire cables, each one of which will be capable of handling and depositing about 1,000 tons in ten hours. Consequently the work can be completed in from four to five years, and, if it need be, in less time."

On page 27 of the same paper it is stated that—

"At the site of the Ochoa Dam, gravel, clay, and rock, in the order named are shown by the borings."

On pages 20 and 21 it is stated that the weir on the crest of the dam is to have a length of 1,250 ft., with its sill at elevation 105, 1 ft. below the water surface, while the San Carlos Ridge weirs, with a length of 1,200 ft., have their sills at elevation 103.5, 2½ ft. below water surface. The company assumes, therefore, that there will be at all times streams of at least these depths flowing over the weirs, and computes the corresponding discharge at 14,200 cu. ft. per second, with the water surface at normal level, viz., elevation 106. The cubic contents of the dam, as above described, is given in the company's estimates of 1890 as 880,000 cu. yds.; but this has recently been increased 50%, and appears in the estimates of August, 1895, as 1,200,000 cu. yds.

It is not known upon what basis the company assumes that the slope of the river from the lake to the dam will be 4 ft. when the water surface at the dam is at an elevation of 106 ft. So far as the Board can determine, the slope at low stage of river and lake will be 0; in other words, that, to prevent the lake from falling below summit level elevation 110, during the dry season, the water surface at Ochoa must be held at the same or a greater elevation, the height of the dam be correspondingly increased, and all sources of waste be stopped. Furthermore, the company assumes (p. 19, Chicago paper) a possible maximum discharge from the watershed with both rivers in full flood, of 63,000 cu ft. per second. No gagings have ever been made at high stages, and reliable data are lacking; but from such sources of information as were accessible to and from observations made by the Board, and by various methods of computation, it is clear that high floods, discharging as much as 125,000, and possibly 150,000, cu. ft. per second, are to be expected at intervals of a few years, and that the dam is likely to be subjected to such floods during construction and subsequently.

The problem at Ochoa, therefore, is to build a dam in opposition to the tremendous and unknown forces of the river floods, while the imperative requirements of the completed structure are that it shall be permanent beyond peradventure and practically impermeable. In a structure so important as this, where failure would mean destruction to property and population from the dam to the sea, and suspension for several years of navigation through the canal, only the most secure and stable structure should be considered. It is not a place to practice small economies.

The conditions would be fully met by a masonry dam on a solid rock foundation, if such could be found. No such site is at present known nearer than Machuca Rapids, 17 miles above, and no search has been made for any. The company's location was fixed with reference to topographical considerations, and the geological investigation was both scanty and unsatisfactory. In January and February, 1888, borings were made in the bed and banks of the river to ascertain the nature and disposition of the subjacent materials. The party was provided merely with earth augers for boring into clay, and with pipes and sand pumps for exploring the sandy bed, but had no drills for penetrating and testing rock, in order, if found, to ascertain its character and quantity.

The borings show that the hills forming the river banks are of clay which is fairly compact. One of these borings, however, shows a considerable depth of sand and gravel underlying clay at a distance of 100 ft. from the bank of the river, and points out a possible source of danger to the abutments. Five borings only were taken in midstream. In four of these nothing but sand is reported to a depth of 24 ft. It is explained that these borings were not carried to greater depths, because the pipes became clogged with gravel, which could not be removed with sand pumps, and for the removal of which no other provision has been made. "Rock" is reported in several borings at depths differing greatly even within short distances, and it is doubtful if rock was found in a single instance, when it is taken into account that the only tool for determining the character of the material was a common auger. The boring taken near the water's edge on the north bank of the river, reached a depth of nearly 14 ft. below the deepest boring in the river bed. This renders it very probable that at least that depth of sand or gravel overlies any harder material, if any, in the center of the stream, and this probability is strengthened by the fact that in the San Juan above the San Carlos the depth of water is as great in some places as 50 or 60 ft., reaching much below sea level.

Nevertheless, an exhaustive search should be made for a suitable site for a masonry dam before accepting one of inferior character. If the route adopted by the company from Ochoa to the sea, through the San Francisco basins to the valley of the Deseado, with some of the undeniable advantages that it would possess is to be retained, the limits for a possible location of the Ochoa Dam are quite narrow. Above the mouth of the San Carlos the deep channel would make it difficult to build masonry foundations, and the canal extension to reach it would be costly. Below Ochoa reconnoissances in the vicinity of the mouth of the Serapiqui and for a few miles above that point have made it almost certain that no site for a high dam exists in that vicinity. The examination would therefore be confined to a stretch of river extending not more than ten or twelve miles

above Ochoa, and not more than eight or ten below it. The Board, however, while insisting upon the necessity for this investigation, cannot prejudge its outcome, and must, in accordance with its instructions, report upon the plan proposed by the company.

The Board has given careful and laborious consideration to the problem of this dam as the most difficult and important individual work in the project, and has sought every means available to investigate the chances of its successful construction. The dam, if finished, could not be overturned or pushed from its base; but questions arise as to the strength of its foundations, as to its resistance to floods during construction, as to making it tight enough to retain in the dry season a sufficient amount of water for canal uses, and as to the practicability of using the completed dam as a weir. It may be said at once, that the structure as proposed, of loose rubble, built in a sand foundation of unknown depth, in conflict with a powerful stream subject to floods, and to be used as a weir after completion for the discharge of the river, has no precedent in any engineering construction.

The idea of the "rock fill" was doubtless suggested by the works of that kind that have been built in the West, and it will be useful to give the particulars in reference to some of these, and, from their success or failure, and the precautions found necessary in building them or the defects which led to their destruction, to extract such lessons as may be applicable to the case in question. Dams of rock fill, with various modifications, have been in use for several years, and have found their principal development in the mining and arid regions of the United States. Several have been built by hydraulic mining companies in California. The California dams usually contain more or less crib work, which is exposed to decay, but the dams are intended to serve only a temporary purpose. The foundation is usually of rock. The slopes are 1 : 1 or steeper, the face being heavy rubble, of the largest stone obtainable from the quarry, and laid with derricks. The smaller stones and refuse are used for the interior filling, which is dumped in. The upstream face is provided with a watertight covering of 3-in. plank, of one, two, and three thicknesses from the top downward to the bottom, secured to the crib work or to timbers anchored into the body of the dam, carefully calked, and fitted at the lower edge to the foundation. Several of these structures will be described.

The English Dam.

The English Dam on the Yuba River, in California, was built in 1856-1858 as a crib dam. It was 110 ft. wide at the foundation, which was on hard trap or shale. The total height above the foundation was about 80 ft. at the center of the dam. Its width at the base was 100 ft. In 1876-77 it was decided to raise the crest of the dam. The timber in the outer face of the crib work was renewed wherever decayed; a mass of rocks was deposited against the downstream slope, the face being heavy dry rubble, laid carefully, and the space between this and the crib filled with loose rock. The downstream face had a slope of nearly 1 : 1. The upper 7 ft. was made wholly of substantial timber work, connected with the watertight plank facing of the original crib work. The crest of the completed dam was 131 ft. above the deepest part of the foundation. From 1858 to 1883 the water in the reservoir was raised every year to the high-water mark, which, in the new structure, was 14 ins. below the crest of the new timber work. No sign of weakness was ever observed.

At 5:30 a. m. of June 18, 1883, a watchman, in making his usual rounds, heard two sharp explosions, and hastened to a point from which he had a view of the dam. The water was pouring through an opening in the upper timber work over the crest of the stonework; in a few moments the crest of the dam for a length of 175 ft. was swept away, and an immense opening was cut in the foundation. In the space of one hour fully 600,000,000 cu. ft. of water were discharged into the canyon below, at the rate of 166,000 cu. ft. per second. The failure is supposed to have been due to the decay of the timber in the crib work, causing a settlement in the rock fill and permitting a sheet of water of considerable depth to pass over it.

The Bowman Dam.

The Bowman Dam was built a short distance below the English Dam, in the same valley. When first built it was a crib dam, 72 ft. high, filled with rock. In 1875-1876 it was raised to its full height, 100 ft., by a rock fill against the downstream side of the crib and above its crest. The completed dam is 425 ft. long on the crest, with slopes of 1 : 1, or a little steeper, on both sides. It was faced with heavy rubble, laid with derricks. On the downstream face the rubble was 15 ft. thick at the base and 6 to 8 ft. thick at the top. The upstream face was covered with plank sheathing, calked and made watertight. The top of the dam was covered with coping of plank anchored into the stonework. At the time of the failure of the English Dam the entire flood passed over the Bowman Dam without injuring it.

Other dams of the same general character still doing service might be cited, but they differ in no important particular from the English and Bowman dams. The essential features were an impermeable foundation, and a crib core, with a watertight plank sheathing. In a few other localities dams have been built without the plank sheathing, and in some respects more nearly comparable with the dam proposed at Ochoa.

Walnut Grove Dam, Arizona.

This dam was built in 1888. It was 420 ft. long on the crest, 110 ft. in height, 138 ft. wide at the base, and 15 ft. wide at the top. Both sides were faced with dry rubble walls 20 ft. thick at the base and 5 ft. thick at the top. The upstream face was covered with a watertight plank sheathing. A mass of loose rock, having a slope of 1 : 1, was piled against the downstream side for half its height. The foundation was rock. During a great flood in February, 1890, the water poured over the crest to a depth of 3 ft. for six hours, when the dam gave way and was entirely destroyed.

Castlewood Dam, Colorado.

This is a loose rock dam, with masonry face, and is 586 ft. long on the crest, 63½ ft. high, 85 ft. wide at the base and 8 ft. wide at the top. The underlying material is a compact bed of clay and hardpan, which was excavated 15 ft. deep over the site of the dam. The upstream slope is 1 : 10, the downstream slope 1 : 1. Both face walls have a thickness of 5 ft., and are laid in cement mortar; the interior filling was laid dry, but each stone was carefully placed. When first built, the crest for a distance of 100 ft. was left 4 ft. lower than the remainder of the dam to form a waste weir, but this has been filled up, and a sluiceway excavated through a rock in a hill forming one of the abutments. The dam is still in good order.

The Pecos Dam, New Mexico.

This dam was built in 1890. It had a crest length of 1,040 ft., with a height of 45 ft. above the lowest point in the foundation. It was built of loose rock, of gypsum and limestone, which was of poor quality, and broken into small pieces in excavating. The upstream slope appears to have been about ½ : 1, and was faced with a hand-laid wall. The downstream slope was 1 : 1 without facing. An earth embankment was built against the upstream side, with an upstream slope of 2 : 1. It was put in dry, and, when the first flood came against it, slid away, and the water poured through the rock fill without doing it any injury. After the flood subsided the embankment was rebuilt in a more thorough manner, with an upstream slope of 3:1. In 1893 there occurred a very high flood, and, the spillway being insufficient, the water poured over the top of the dam to a depth of 5 ins, which was sufficient to cause its speedy destruction.

St. Christopher Dam, France.

The following description of this very interesting example of a rock-fill dam is taken from the Engineering News of Jan. 8, 1887, which is credited by that paper to the Proceedings of the Institution of Civil Engineers:

"This was originally a bank of rough stone 65 ft. high for carrying the canal (Marseilles Canal) across the valley, and constructed with very little care, without any intention of using it as a reservoir dam. When it was determined to adapt it to this purpose the water-tight lining of the canal was removed and the turbid water allowed to sink into the dry stone work. This produced considerable settlement, but at the same time filled up the cavities with deposit. Water was then gradually let into the reservoir. At first large quantities made their way through the dam, but the amount of leakage diminished by degrees and the inner face of the dam was then covered with good masonry, 10 ft. thick at the bottom and 1½ ft. at the top. This was expected to render it water-tight, but did not have this effect, and upon readmitting the water large fissures appeared on the face, particularly near the bottom. Several rows of piles were then driven near the foot and the cracks filled up, and the bank is now practically water-tight."

The Cascade Fill.

The Cascade Fill on the line of the Erie Railroad, has been referred to in connection with the proposed Ochoa Dam, and illustrates so well some of the features of rock fills that a description is proper in this connection. The track of the Erie Railroad crosses the valley of Cascade Creek, 175 ft. above the bottom of the gorge. It was originally carried on a timber arch which was replaced about 1860 by an embankment. In order to avoid the use of a culvert through the embankment the lower portion was made of clean riprap, which formed a drain for the creek. The upper portion was made of smaller stone, and with anticipation that the rainfall might not pass the largest floods a tunnel was driven around one end of the fill through the rock of the hill, as a discharge culvert. In 1875 the tunnel discharged a large amount of water for the first time. As late as 1888 the rock fill continued to pass the ordinary drainage and even moderate floods, but since that time it has become practically water-tight and the discharge is through the tunnel.

The Ochoa Dam and Other Rock-Fill Dams Compared.

The rock-fill dams which have been cited differ from the proposed Ochoa Dam in many respects, and the limits within which they may be regarded as precedents must be kept clearly in mind. In no case has the rock fill been relied upon to make a water-tight dam. A plank sheathing or a skin of masonry laid in cement, or a carefully built embankment has been adopted as an absolutely necessary feature. In the case of the Cascade Fill, the riprap was intended to act as a substitute for a culvert, and answered its purpose sufficiently for many years except for very heavy rains. In nearly all cases the foundation is rock, but there are two notable exceptions. The first is the Castlewood Dam, in Colorado, where the foundation is a compact bed of clay and hardpan. The second is the St. Christopher, where much settlement and leakage resulted, which was finally stopped by sheet piling.

The English, Walnut Grove, and Pecos dams failed immediately or within a few hours when the water passed over their crests, and they became weirs. The failure of the English Dam was caused, probably, by a settlement of the stone breaking the connection between the new timberwork on the summit of the dam and the older crib work below and permitting the new work to be swept away; but whatever the cause may have been, it is an important fact that as soon as a sheet of water 6 ft. or more in depth commenced to pass over the unprotected crest of the rock-fill dam its destruction followed in a few moments. The resistance of the Bowman Dam, over which the vast liberated flood passed so quickly, was probably due to the protection of the crest by timberwork, which prevented the formation of a breach in the rock fill, and it may be presumed that the downstream face of the dam had been laid with care, but it must be remembered that the trial lasted only about an hour.

There has been much dispute as to the care with which the Walnut Grove Dam was built; the slopes were considerably steeper than 1:1, and although the walls on both sides were hand laid, the dam failed within six hours after having been overtopped with 3 ft. of water. The failure of the Pecos Dam is not so surprising, for the material of which it was composed appears to have been already so finely broken that it could offer little resistance to a strong current, and its speedy failure when overtopped was inevitable. No case is known of an existing rock-fill dam where its use as a weir is intended, and the failures above cited point out the danger, which there would be no justification for incurring, for the completed structure at Ochoa, where the interests involved will be so vast. It is inevitable, however, that during the construction of the Ochoa Dam the flood waters will pass over it, and the question of their probable effect is of great importance. The conditions at Ochoa will be in some respects more favorable, in some respects less favorable than in the cases above mentioned; the material to be used will be in large masses and the downstream slope will be flatter. On the other hand, the annual floods of the San Juan will be discharged over the mound for several years during its construction. If a flood like that of 1888 occurs during this period, the depth of the sheet of water passing over the dam will be 10 ft. or more in thickness, and will exert an enormous force to displace the stones on the crest of the downstream slope, a force which they will be the less able to resist because in the earlier stages of the work it will be impossible to arrange them with any regularity so as to form a dry wall or paved surface.

The great weirs known as "anicuts" built across the wide, flat, sandy, river beds of India are instructive in this connection. While these weirs are only 10 to 20 ft. in height above the bed of the river, immense floods pass over them, sometimes for a depth of 20 ft. The weirs are built during the season of low water, when the flow of the river is small and can be diverted, and any repairs that may be necessary can be made during the long dry season that presently follows the brief rainy season. The river bed for a distance of 150 ft. or more below the weir is protected by a heavy layer of riprap, covered by a paving of large stones laid by hand as close as possible, with their longest dimension vertical. A system of concrete or rubble walls whose foundations generally penetrate several feet into the river bed divides this protecting apron into areas of 20 to 30 ft. square, so as to confine the limits of injury which any portion may receive. The slope of the apron is never steeper than 10 horizontal to 1 vertical, and more than 20 : 1.

During the construction of the Ochoa Dam the river can not be diverted either wholly or in part until the dam has been built to a considerable height above the present river bed, and the top and downstream slope of the dam, corresponding at this stage with the apron of a weir in India, cannot be protected by a regularly laid surface. The stones, however, may be very much larger, and thus compensate somewhat for irregularity of arrangement. Several of the larger Indian weirs resemble the Ochoa Dam in that they are built on sand extending far below the foundations, but they are never of great height, and the penetration of the masonry of the weir below the river bed is usually greater than the elevation of the crest above the river bed. It would be impracticable to realize a like condition at Ochoa.

It appears from this account of typical existing dams that, although rock-fill dams are not new, and although weirs have been built on sand and maintained successfully, the Ochoa Dam is actually without precedent in its more serious aspects, and its construction will be far more difficult than any that have been mentioned. The successful rock-fill dams have impervious foundations, and are made watertight by sheathing or masonry. The materials in them are in great part hand laid, adding greatly to their stability, and none of them has been built in conflict with the forces of a great river or was intended to be used as a weir for the discharge of floods. As to this last point the Board is clear in its judgment that no such endeavor should be made in the case of the Ochoa Dam, as involving an unwarrantable hazard to the safety of the structure and the canal navigation.

It will be seen that the construction of a loose rubble dam without masonry and lacking bond and coherence, resting in a bed of sand of unknown depth, intended to endure the constant flow of water over its crest and down its rear slopes, and to resist the passage of floods of many feet depth, depending for its maintenance solely upon the stability that the individual stones exposed to the impact and power of the stream may be able to derive from their weight and contact with the adjacent pieces of rubble, has little resemblance to the low and carefully hand-packed anicuts built during the dry season, or to rock fills of the mining regions, built dry on rock, with crib work whose defect is its perishability, and which are not intended to bear an overflow.

In the case of the Ochoa Dam, while there are no precedents of similar design that can usefully be studied as a guide, there are many failures of dams of various types that may wisely be considered as warnings when the subtle and often incalculable power of a large body of water under high pressure and in full movement is in question.

How the Ochoa Dam Should be Built if the Rock Fill is Adopted.

Although evidently invested with special and unusual difficulties, it can not, therefore, be inferred that the construction of a dam at Ochoa is to be regarded as impracticable or beyond the resources of modern engineering. Engineers are loath to admit that anything not forbidden by the known laws of nature is impossible, provided the need of doing it and the means of paying for it are commensurate with the magnitude of the undertaking; but no one will deny that the formidable nature of the task and the seriousness of the interests depending upon its successful execution make greater the urgency that every detail and particular affecting the problem shall be closely studied and accurately determined, without doubt or uncertainty, as far as the methods and appliances of modern science shall avail to ascertain them, in order that the plans of construction may be intelligently formulated, the necessary appliances be considered to meet contingencies, the risk and difficulties of construction and maintenance be reduced to a minimum, and a fairly adequate estimate be made of the cost of the completed work, and of the time required to build it. There are chances and hazards in all great undertakings, and the history, both technical and financial, of engineering constructions, especially those dealing with hydraulic problems, but emphasizes the necessity of thorough exploration, and full and precise ascertainment of essential facts before proceeding with the actual execution and expenditure for construction.

The Board has endeavored, notwithstanding the lack of proper data, to formulate some views as to what might seem to be the safest method of constructing the dam, and as to the dimensions it should have. One view contemplates the building of the dam subject to the floods of the river until it should be raised to such an altitude as to admit of completing the upper part rapidly in one low-water season. The second considers the advantage of constructing sluices in the San Carlos Ridge of such dimensions as should give relief in part or altogether, with the idea, subsequent to the completion of the dam, of continuing the sluices in service as a means of regulating the water discharge, and the maintenance within proper or possible limits of the summit level elevation.

In view of the probability that the work may be subjected to a flood so great as 150,000 cu. ft. per second, the Board considers that this contingency should be regarded as a datum for safety in arranging the details of construction. Another datum regulates the height. The maintenance of the lake level at a minimum of 110 will probably involve the necessity of holding it at times at 112 or even more. The Ochoa Dam must meet this contingency, and its crest elevation, allowing for possible subsidence and a proper free board, should be 120.

The weakest point of a dam built as the company proposes would probably be at the river bank, where the loose rock will meet the steep clay slope. The method proposed for protecting this point by lines of sheet piling and concrete core seems entirely inadequate. A better construction would involve the use of a caisson on each side of the river, located so as to be partly in the river channel and partly in the firm clay bank, and sunk by the pneumatic process to bed rock if within reach by that means, or if not, at least below reach of scour. It seems probable that either bed rock or a mass of bowlders would be found near sea level, elevation 0. The caisson should be surmounted by a concrete wall, extending up the hillside beyond the caisson to the highest elevation to be reached by the water surface after the completion of the dam, say 114 or 116. A trench 20 ft. or so in depth, or deeper if necessary to reach firm material, should be excavated in the hillside for the core wall. This work done, the river banks and hillsides below high-water level should be covered with a heavy mass of large stones and an additional amount held in reserve before depositing any rock in the river. The result of this would be to contract somewhat the width of the river channel, which would at once scour out so as to maintain its normal cross section. A considerable scour would be desirable, because it is important that the rock mass be sunk deeply into the river bed, since, if rock or a bed of bowlders or heavy gravel can be reached, the safety of the structure will be increased greatly. In depositing rock in the river those methods should be used which will induce scour, and possibly the building out from each side may best answer this purpose.

The proposition of the company to build the main portion of the dam with stones of large size, with only enough small pieces to fill voids, is sound, and precautions should be taken to have the surface of the mound covered with the heaviest rock obtainable prior to every flood season. If the work is carried up over the whole width of the stream, a regular cross-section should be maintained, so that the force of the flood will not be concentrated at any one point. The downstream slope should be made very flat—10 : 1 will be none too flat, and will give trouble enough in maintaining it. As the work rises the danger of injury by floods will increase. Should sand under the mound scour out at any point a settlement would occur, a channel would be formed through the mound, and the destructive power of the current be greatly increased. If, however, the mound can be successfully raised to an elevation of 70 ft. above sea level, or 35 ft. above the present bed of the river, it will be then possible to build the remainder of the dam to full height in a single low-water season, the reduced flow of the river spouting through the interstices of the dam, by using temporarily a steeper downstream slope of 3 or 4 : 1. This done, and weirs provided elsewhere for discharging the river, the hazards of construction will be passed but until this stage is reached the work will be subject to danger from every flood and the contingent risks will be great. It is believed that by some such means as is outlined, subject to modifications as actual experience may prove necessary, a rock mound could be carried across the river. It should then be strengthened by completing the full-rock section.

The rock mound would be quite permeable, and the water pressure against it would vary with the volume of the discharge. To make it hold water, an embankment, which would form the real dam, the rock mound serving as its support, must be built on the upstream side. It is proposed to make the embankment of fine stone, gravel, clay, etc., with the view that a quantity of these materials should be carried well into the rock mound. An embankment composed largely of clay dumped in the water would take a much flatter slope than 3 : 1. For these reasons the quantity estimated by the company would have to be increased largely, and means may have to be adopted, not contemplated by the company, to render the dam tight enough to answer its purpose, as the permissible leakage is much less than the company has assumed. By the addition of the embankment, and the retardation by friction of the flow of water through the underlying sand bed, the dam will be rendered more secure from undercutting and consequent settlement; but some doubt as to ultimate security will still remain. Confidence would be gained to a certain extent during the construction of the dam, if no breaches were caused by the annual floods, but it would require a considerable period of time after the completion of the dam to allay all apprehension. If a site can be found where the dam can be built above a rock or other stable foundation, the permanence of the structure will be rendered much more probable and the uncertainties of construction reduced. If such a dam becomes breached with the great volume of water standing at a high level against it, destruction would follow quickly. The crest, therefore, should be raised so far above the surface of the water in the pool that a considerable settlement could be sustained without sinking the crest below the water surface.

A study has been made to ascertain if, by the construction of auxiliary sluices at convenient points in the San Carlos ridge, the river could be in part or wholly diverted, so as to reduce the volume and velocity of flood discharge over the dam, diminish the possible risks during construction, and subsequently aid in regulating the elevation of summit level. Following a preliminary discussion of this subject with the Board, the company has added to its estimate the cost of two sluices with openings 20 ft. wide and 25 ft. high; but the sills are put at elevation 64, and the river surface would therefore have to rise about 16 or 18 ft. before the sluices could begin to discharge. Furthermore, the company largely underestimates the highest possible flood at 63,000 cu. ft. per second (see Chicago paper, p. 19), while the Board considers that a maximum of 150,000 is possible, and, for security, should be assumed.

The construction of sluices or other means of diverting the entire possible flow at the outset, prior to beginning work on the dam, would involve so serious a cost as to make it prohibitory; but if the sluices were so planned as to begin the relief of the dam at a point where the effect of flood discharge would become dangerous, and thereafter furnish an increasing measure of assistance, the risks involved would be reduced and construction facilitated. After construction, the sluices could then be called upon, if necessary, to discharge a full flood.

For the purpose in question eight masonry sluices were assumed, with openings 20 × 25 ft. and sills at elevation 58. The crowns would therefore be at elevation 83, and when the water surface, as raised by the dam, should reach elevation 100, the sluices would be capable of discharging the full volume of 150,000 ft. per second with a head of water of 17 ft. over them. As the average low-water surface of the river is at about elevation 48, the dam in the earlier stages of construction must in any case be without relief, and with the gradual raising of the mound, the floods would act with increasing force and effect; but at elevation 58 the sluices would begin to co-operate.

The discussion of the balancing action of the sluices under the varying conditions of flood discharge and surface elevation of river at the several stages is complicated and quite interesting, the more so as the sluices in the San Carlos Valley are six miles distant from the dam in the San Juan, measuring along the river channels; but the subject is too technical for incorporation in this report. The period of greatest danger to the dam will be when its crest is built up to about elevation 65 to 70—say, 17 to 22 ft. above low water—and at this stage subjected to a flood of 150,000 cu. ft. per second.

The sluices would be about two-thirds full, and be discharging about 60,000 cu. ft. The flood pouring over the dam would be about 90,000 cu. ft., the depth over the crest of the dam would be over 9 ft., and the water would descend the rear slope in a solid mass 5½ ft. deep, with a velocity of nearly 13 ft. per second, or nearly 9 miles per hour. Without the aid of the sluices the depth on the crest would be about 13 ft. and the velocity down the slope 25 ft. per second. These figures, though theoretical merely, may serve to give some idea of the magnitude of the destructive forces to which the rock-fill structure will be exposed and the hazards involved in the attempt to build it in such unprecedented conditions.

The cost of the sluices would not be less than $1,500,000, allowing for necessary excavations and protection for site and approaches. It may be observed that the construction of these sluices in a clay bank, to be operated under high head, will itself be no mean task, if due precautions are to be taken to insure the efficiency and safety of the structure after completion.

It may be proper to give the dimensions which the Board believes the Ochoa Dam would be likely to have, if successfully erected. The crest of the dam at elevation 120; its base in the sand at about elevation 15; total height, 105 ft. The rock-fill portion would be 20 ft. wide on top; base, 950 ft. rear slope, from 10 : 1 at base to 4 : 1 at top; front slope, 1 : 1. The embankment against it on the upstream side would be 20 ft. wide on top (making 40 ft. total width of summit) and an upstream slope of 5 : 1 and base 340 ft. The volume of the rock fill would be 2,000,000 cu. yds. and of the embankment 600,000 cu. yds. Total volume, 2,600,000 cu. yds.; total base length, 1,290 ft.

One or more lines of sheet piling across the river under the embankment would tend to diminish the movement of water through the subjacent sand, augment the safety of the dam, and reduce leakage. The examination of the project for the dam shows for itself its unsatisfactory character. Should further exploration develop a more advantageous site with conditions positively ascertained, a safer construction could be designed. The case is not one where unnecessary risks should be run, or plans based upon insufficient data be adopted. With the information now available the Board can not undertake to commit itself to more than a tentative and approximate estimate of what the Ochoa Dam may cost, and the item of $4,000,000 entered in the schedule may be either increased or diminished as the conditions shall become better known.

The San Carlos Ridge.

As an adjunct to the Ochoa Dam and the most suitable location for such sluices, weirs, etc., as may be needed to discharge the surplus drainage after construction of the dam, it will be convenient to refer to the San Carlos embankment line in connection with the main work. The embankments proposed by the company for an assumed water-surface elevation of 106 are 23 in number, with an aggregate length of crest of about 1¼ miles; but for the greater elevation deemed necessary by the Board, viz., 110, the number will be increased to 25 and the aggregate length to 1½ miles. There is nothing in the construction of these embankments that presents special difficulty.

The length of weir, with movable dams, provisionally estimated by the Board as needful for the flood discharge, is about 4,000 ft., which, with a head of 4½ ft., would discharge approximately 130,000 cu. ft. per second. If sluices are used in conjunction, the weir length may be reduced, or possibly omitted altogether. In any case, since upon these adjustable weirs or sluices, or both, will depend the water-surface summit elevation required, the details, when finally adjusted, must be of the most elaborate and efficient character, with ample mechanical appliances for speedy and safe adaptation to varying needs, including telegraphic communication up the valleys of the San Carlos and San Juan.

THE SAN JUAN RIVER.

The San Juan receives the surplus waters of lakes Managua and Nicaragua and of the territory draining into them, a total area that has been roughly estimated at 11,400 sq. miles, to which is to be added the 4,000 sq. miles of the river valley proper. It is a large stream at the outset, having a flow at mean low stages at Fort San Carlos, where it leaves the lake, of 10,000 or 12,000 cu. ft. per second, with a width of 800 ft. and an average channel depth of 10 ft. The total length of the river from the lake to the Caribbean is 119 miles, in which distance it falls 102 ft. from mean low lake to mean sea level, with slopes ranging from less than an inch to over a foot per mile, not considering the several rapids, and an average slope of 10 ins. per mile.

The navigation of the upper 50 miles is obstructed by four rapids, where rocky reefs cross the river valley, causing local steep descents of 6 or 7 ft. each, and sustaining the intervening quiet stretches. These rapids, in their order, proceeding downstream, are at distances from the lake as follows: Toro, 27 miles; Castillo, 37 miles; Balas, 44 miles, and Machuca, 48 miles. At low stages the river boats can not ascend these rapids, with the exception of Balas.

From Machuca to where the San Carlos River—the most important affluent of the San Juan—joins the main stream, 65½ miles from the lake, is 17 miles of a deep, quiet stretch known as the Agua Muerte. Three and one-half miles below the mouth of the San Carlos, and 60 miles from the lake, the company proposes to build the Ochoa Dam, the purpose of which, in conjunction with auxiliary works, is to hold back the waters of the San Juan and San Carlos and maintain the surface of Lake Nicaragua at not less than the elevation of 110 ft. above mean sea level. Just above Ochoa the canal is to leave the river and go eastward on an independent line.

With the Ochoa Dam raised to the proper height to sustain the high lake level, the San Juan Valley will be flooded for the entire 60 miles upward to the lake, and become a part of the summit level, carrying the canal navigation.

The Machuca and Balas rapids will thereby be drowned to a depth sufficient for deep navigation, but at Castillo some rock excavation in the river bed will be necessary, and still more at Toro. From Toro upward to the lake for nearly the entire distance of 27 miles the elevation of the river bed is such as to call for almost continuous excavation to secure the requisite width and depth of channel.

The materials to be removed are supposed to be rock, bowlders, gravel, clay, sand, and mud, in unknown proportions and practically unknown amounts. The company proposes for its channel section through these obstructions a depth of 28 ft. and a bottom width of 125 ft., with slopes in rock cutting of 1 : 1 and in dredgeable material of 3 : 1. If 28 ft. had been adopted as the standard depth, to which the several sections of the navigation should conform, there might be no compelling reason for making the river channel of greater depth, but, in fact, the company's project calls for 30 ft. throughout, except in the river and in the two sea-level canals that connect directly with the harbors.

No reason is assigned by the company for making these exceptions, and the Board considers them inexpedient as reducing by 2 ft. the capacity of the entire system, and that the full depth of 30 ft. should be carried through from sea to sea, as in better conformity with the present and prospective requirements of commerce and the integrity of the undertaking. Especially is this the case where, as in the San Juan, much of the excavation is in rock and other hard material. The Board also considers that the proposed bottom width, 125 ft., for the river channel is insufficient.

The navigation conditions will be quite different from those in a canal between visible banks where the course of vessels is straightly guided, and where in passing one or the other can tie up. The deepened river channel will be submerged; it will carry whatever may be at times the maximum current, and must follow the windings of the valley through curves of greater or less radius. Furthermore, during flood the surface currents may not run true with the channels but at some angle with it; the visible surface width will be that of the flooded valley, and for close steering vessels must rely upon buoys and such other artificial aids to navigation as may be provided. In such circumstances a bottom width barely sufficient to enable two deep vessels to pass in a canal is quite inadequate in an open river, and for safety a single vessel even would need to proceed with great caution to avoid grounding.

In this connection some analagous data may be of service. Colonel Childs in designing his canal for 17 ft. depth made the bottom width 50 ft., but in the river the bottom width of cuts through the bars was to be three times greater, viz., 150 ft. For a canal 30 ft. deep, with bottom width of 80 and 100 ft., the river channel, using the same proportion, would be from 240 to 300 ft. bottom width. For the 20-21-ft. channel in the Great Lakes, through the St. Marys, St. Clair, and Detroit rivers, and the connecting waterways, intended for the use of vessels of less draft than that of war ships and ocean steamers, the minimum width of dredged waterway is 300 ft., and in bends and in difficult places this is enlarged to 400, 600, and 800 ft., those dimensions being determined by considerations of safety and reasonable speed. For continuing the lake navigation to tide water, a recently proposed ship canal, to have a depth of 26 ft., is designed with a bottom width of 300 ft. The Board therefore considers that the San Juan River channel section should be not less than 30 ft. deep and 250 ft. wide, broadening around bends to 300 and 400 ft., according to degree of curvature. There is no means of ascertaining, with any approximation to accuracy, what may be the quantities and proportions of the materials to be removed, whatever may be the cross section.

It appears that the canal company has made no surveys or examinations of the 69 miles of river between Ochoa and the lake, with the exception of a partial survey by compass, which was laid aside as valueless. The latest information, therefore, is that obtained by the Lull expedition in 1872, when a part gradienter and part spirit-level line was run and some soundings taken. The indications of the nature and distribution of the materials composing the river bed, as furnished by the sounding lead and noted on the Lull map, constitute nearly all that is known in the matter.

The company's tabulated estimates contain items of 398,613 cu. yds. of rock excavation, 422,540 cu. yds. of earth excavation above water (to straighten bends), and 2,150,900 cu. yds. of dredging, as representing the quantities involved in the deepening of the San Juan, and, upon inquiry as to the basis of these amounts, the company submitted a profile stated to have been derived from the Lull survey, showing the elevation and arrangement of the materials in the bed. Upon computation of the quantities indicated on the profile with the company's cross section, 28 by 125 ft., the amounts came out as rock excavation 1,424,000 cu. yds., and dredging 3,464,000. No explanation of the discrepancy is given other than the supposition that some erroneous profile must have been used, of which there is no note among the company's records. Using the same profile as a basis with the increased cross section considered desirable by the Board, viz., 30 by 250 ft., the computed amounts are, respectively, for rock, 3,754,000 cu. yds., and for dredging, 8,526,000 cu. yds.

These figures have, in fact, no valid basis, as the profile furnished by the company is little more than guesswork, and it is not believed that the total rock excavation indicated will be required; but they do show clearly how formidable may be the cost of a proper deepening of the San Juan, and how urgent is the necessity for a thorough and reliable ascertainment of the facts. The omission of the company to determine these seems inexplicable, especially in view of the statement made on page 3 of the final report by the chief engineer, corrected to January, 1890, as follows:

"Third. Local surveys have been made in the river San Juan at all places where the data on hand were deemed insufficient for a close estimate of the amount and cost of excavation needed, or to determine with reasonable precision the difficulties likely to be encountered in the construction of dams, embankments, or other works entering as important factors in the general scheme."

In the absence of better data it still appears necessary to use the Lull profile as a basis for an estimate, with such modifications as may otherwise suggest themselves.

Colonel Childs does not seem to have noted any rock in the river bed until near Toro Rapids, and the notes of the discarded compass survey made by the company give similar indications, so that the large rock excavation called for by the Lull profile may be much in excess.

There is another point in this connection: The company assumes that the slope of the river surface, after being raised by the Ochoa Dam, will be ⅝ in. to the mile, the same as is ascribed to two of the quietest sections at low water, and, therefore, that the crest of the dam

at 106 will hold the lake up to 110, with 4 ft. of slope between the two. The Board has not been able to obtain any evidence of this assumed low-water slope, but this is not material, for the reason that, as elsewhere stated, the Board believes that for a reliable maintenance of the lake level at 110 the crest of the Ochoa Dam must be so raised as to secure the same or a greater elevation at that point also; in other words, that the water surface through the valley must be assumed as horizontal during the dry season. In such case, the slope disappearing with the raising of the Ochoa Dam, there would seem to be an opportunity for a considerable reduction in the depth of excavation needed at Castillo and from Toro upward, and a recomputation of quantities from this datum, with the additional assumption that from station 4,150 on the profile, above Toro to the lake, no rock excavation will really be called for, would furnish the following figures: Rock excavation, 1,722,000 cu. yds.; dredging, 8,285,000 cu. yds.

Unfortunately this reduction is not permissible, for the reason that, as shown in the discussion of "Maintenance of summit level," in order to prevent the lake from rising during the wet season to such a height as would involve heavy damages to improved property bordering on its shores, it will be necessary to draw down the summit level at Ochoa to such a point as to enable the river to discharge the threatening accumulations in the lake, and, therefore, the 4-ft. slope, assumed incorrectly by the company as practicable at low stages, may be imperative during high stages or, assuming the lake capable of control, during the season of heavy rainfall. The total quantities given by Table 4 must therefore be used until better information is available as a means of entering the amounts in the estimates.

There are several bends in the river of such radii as probably to necessitate considerable straightening by cutting off projecting points, or the employment of special means for enabling large vessels to navigate them. There is no means of computing the amount of excavation required. The company's estimates contain an item of 422,540 cu. yds. for this purpose, but the basis for this can not be ascertained. If this item be increased in somewhat similar proportion to the other data, it will appear in the provisional estimates as 1,500,000 cu. yds., which is entered as earth, although some of it may prove to be rock.

The disposition to be made of the large amount of material excavated from the river bed is a matter calling for careful consideration. According to a printed specification for dredge work, prepared by the company as a basis for inviting bids, it is to be "deposited on the banks or in such places as the chief engineer may designate." If put ashore an extra cost adding largely to the estimates must be provided for, and it is doubtful if in the upper section, where the navigation is comparatively restricted and the excavation large, it will be prudent to dump it in the vicinity of the dredged channel and within reach of the river current. Possibly a portion of the materials to be removed is such as may be used to construct training dikes parallel with the channel, behind which the sand or other lighter material could be placed, but details of this kind must depend upon a proper survey and ascertainment of particulars.

There is a discrepancy in the stated length of the river from Fort San Carlos to Ochoa that should be noted. As derived from Childs, the distance is 68.71 miles; according to Lull it is 69 miles. The report of 1885 and subsequent reports put it at 65.50. As no survey was made later than Lull's, the earlier figures should be taken.

LAKE NICARAGUA.

The southeastern end of the lake, near Fort San Carlos, where the San Juan river leaves and the Frio enters, is a shallow expanse, deepening gradually with a flat bottom slope. The company's map indicates that the 30-ft. contour of depth, with the lake at elevation 110, lies 14 miles offshore, and a ship channel of this length is to be dredged on a straight line, bearing about north 70° west from the San Juan outlet.

As proposed by the company, the channel will be 30 ft. deep and 150 ft. wide on the bottom, with side slopes of 3 : 1. On this basis the company's estimated amount of dredging is 4,726,076 cu. yds., but there is some error in this, as the amount stated corresponds more nearly to a bottom width of 125 ft., and the actual amount as recomputed is much greater, viz., 5,645,000 cu. yds., according to the company's profile, or 5,143,000 cu. yds. according to the company's chart.

For reasons stated in discussing the width of the river channel the Board is of opinion that the bottom width of the lake channel should be not less than 300 ft. The course of vessels, although straight, is in the open lake subject to such irregular currents as may exist in so large a body of water and to the action of the winds. The information on this point is that storms are infrequent, although squalls of no great violence or duration occur, and that the prevalent wind is moderate to fresh and a continuation of the east-northeast trade from the Caribbean.

The proposed slope of 3 : 1 is also quite inadequate. The material composing the bottom is on top a liquid mud, stiffening downward into harder mud or clay. The Board made soundings along the channel line from a point about 5 miles out in the lake, toward the San Juan outlet, and at intervals of about a mile took means to thrust a long pole into the bottom, with the following results: At 5 miles out, depth of water 10 ft., depth of mud 8 ft.; at 4 miles, water 9 ft., mud 9 ft.; at 3 miles, water 8 ft., mud 9¼ ft.; at 2 miles, water 7¾ ft., mud 9 ft., and at 1 mile from shore, water 6 ft., mud 11½ ft. The mud was noted as soft and gritless, a derivative of volcanic ash or the like, probably mixed with more or less vegetable matter. Such material as this could never stand at the submerged slope of 3 : 1, particularly as the currents due to the action of vessels' screws are very destructive to channel banks.

The closest analogy to work of the kind proposed is to be found in the dredging in Mobile Bay, where a ship channel of 24 ft. depth, with a bottom width of 280 ft., has for many years been in course of construction and the physical conditions are quite comparable with those in Lake Nicaragua. The Mobile channel has a total length of some 23 miles, and the underwater slopes assumed by the different materials dredged through are as follows: Very hard sand, 3 : 1 and 4 : 1; hard sand, mixed with shell, 6 : 1 and 8 : 1; stiff mud, 8 : 1 and 12 : 1; soft to liquid mud, 14 : 1 and 20 : 1. The description of this soft mud, as given by the engineer officer in charge, to whom the Board is indebted for these and other particulars, "a thick soup underlaid by a stiff mud," is precisely applicable to the greater part of the Lake Nicaragua material.

The Board therefore considers that an assumed slope of 10 : 1 is a very moderate datum for computation. Using this and a bottom width of 300 ft., the quantity to be dredged according to the company's profile is 12,873,000 cu. yds., and as computed from the company's map 11,724,000, an average of 12,300,000, and this is more likely to be exceeded than reduced unless some means be taken to maintain the channel banks from inflow of adjacent material. Sheet piling would do this, and reduce the cross section, but for so long a channel it would be a costly item, and it seems likely that this may be avoided by following a Dutch practice and depositing the stiffer material excavated from the bottom of the cut so as to form a submerged wall or bank parallel with the channel which will crush down through the semi-liquid mud and hold it back. Beyond this, half a mile or more from the channel, the softer mud can be pumped by means of hydraulic dredges. With this method of protection, however, it would not be prudent to diminish the cross section of the channel.

Beyond the dredged channel the sailing course is through the open lake for a distance given by Colonel Childs as 56½ miles to the west coast, leaving Balsillas Islands to the northward and the Solentiname and Sonate groups to the southward, and passing about 4 miles to the southward of the island from which rise the volcanoes of Madera and Ometepe. This island has a total length of 20 miles, its northwest end about 5 miles and its southeast end about 11 miles distant from the west coast, sheltering the canal entrance from north-northeast to east by south from the prevalent winds coming from about east-northeast.

This continuation of the trade wind is represented to blow steadily, with a force from gentle to fresh, during the greater portion of the year. The strongest winds are said to be from the north and west of north. Their force can not in any case be great, as is proved by the endurance of the frail, half-filled timber cribs, the construction and condition of which was noted by the Board, which compose the landing piers at San Jorge, 4½ miles north of the canal entrance, and at Granada, near the northwestern end of the lake, 50 miles distant, where the exposure is about the same. Under the lee of the islands is an admirable harbor for vessels of all draft, with good holding ground and entire shelter.

The Canal Entrance on the West Side of Lake Nicaragua.

The west shore of the lake is rocky, and considerable excavation will be required to carry 30 ft. into the canal, the contour of that depth, with the lake at 110, lying about 1,600 ft. from the shore line. The canal entrance is on the lee shore, and while the exposure is not great, it may be desirable to protect it by artificial works. The company proposed for this purpose two piers, starting from the sides of the canal, and extending into the lake on diverging lines to a length, respectively, of 1,800 and 2,400 ft., the entrance width at the outer end of the shorter pier being 600 ft. This funnel-shaped entrance is not desirable in circumstances of this kind as tending to accumulate such sea as may be running shoreward, and the Board considers that it would be preferable to separate the piers at the shore ends, placing them 800 or more feet apart, and converging the extremities to about 500 ft. for the entrance width. These piers may be built of crib work, filled with stone derived from the local excavation, which is in ample quantity for that purpose. In addition to these, additional short guide piers of timber work, about 400 ft. in length, would be required to sustain the canal banks where they pass through the shore line. The amounts estimated by the company are sufficient to cover the cost of these constructions.

THE WESTERN DIVISION—LAKE NICARAGUA TO THE PACIFIC.

Lake to Tide Lock near Brito.

The territory separating the lake and the Pacific has been quite thoroughly explored in the course of the several surveys made at various times, and the Lajas-Rio Grande route, originally selected by Colonel Childs in 1850 and now adopted by the canal company, doubtless offers on the whole the greatest advantages. The country is open and rolling, with moderate elevations, and presents no serious obstacles to canal construction.

The canal line leaves the lake shore 900 ft. north of the mouth of the River Lajas on a course south 60° west up the valley of that stream, crossing the river four times within a distance of 1½ miles. For the greater part of this distance a new channel is to be made, to divert the river to the south side of the canal, and prevent interference with it. Westward of the last crossing, the river valley bears more to the southward, while the canal continues through an open country across a gradually ascending plain toward the summit of the divide. After some curvature, the summit is reached, 5 miles from the lake, at an elevation of 154 ft. above mean tide, or 44 ft. above the summit level elevation 110, that is to be maintained in Lake Nicaragua, giving a maximum depth of cut of 74 ft.

Passing the summit the line enters the drainage basin of the Rio Grande and meets the river at a distance of 7½ miles from the lake, at the head of a narrow valley or gorge, and thence follows the general course of the stream to the Pacific at Brito. This portion of the route is heavily timbered. In the gorge, which is 1¾ miles long, the line is mainly in curves, with a minimum radius of 4,300 ft. Of the whole distance from the lake to the Pacific about two-thirds consists of tangents and one-third of curves, with radii of from 4,300 to 17,000 ft.

The width of the gorge is insufficient to furnish separate accommodation for both canal and river. This complication led Commander Lull, in 1872, to seek a separate route, and he adopted a line which leaves Lake Nicaragua 3½ miles to the northward of the mouth of the Lajas, and, following the valley of the Medio and one of its small tributaries, crosses the divide with an elevation of 243 ft. above mean tide, and then joins the Lajas line at the western end of the Rio Grande gorge. By this route the water of the river could be kept in its own channel by making a few cut-offs, but it had no other important advantage, while the depth of the divide cut and the amount of excavation were much greater. The company has adopted the Lajas line, returning to the Childs location.

From the outlet of the gorge, two alternative routes have been located by the company—the earlier one continuing the canal to the sea, the other damming the Rio Grande 3½ miles from the Pacific for the formation of a large basin, which would prolong the summit level 4½ miles westward. By the first route, called the "low-level line," the canal in excavation and embankment follows the right bank of the Rio Grande through the gradually sloping valley to Brito, descending by four locks, placed at natural sites, or, in their absence, where the natural slope of the valley requires; the first lock with a descent of 25 ft., terminating the summit level, is placed in a hill at the west end of the gorge, 9.2 miles from the lake shore; the second lock, with a descent of 30 ft., is placed in the valley at a farther distance of 1.6 miles or 10.8 from the lake; the third lock, also with a descent of 30 ft., is 3.6 miles farther, or 14.4 miles from the lake; the fourth or tide lock, with a descent of 25 ft. at mean tide, or 29½ ft. at ordinary low tide, is 2 miles farther, or 16.4 miles from the lake. The distance from the tide lock to the ... tour in the Pacific is 1.3 miles, and the total distance from the lake to this depth is 17.7 miles.

West of the summit level the Rio Grande has no important tributaries on its left bank. On its right bank it receives the Tola, which has its sources ... miles to the northward. The Tola is ordinarily an insignificant creek, quite dry at times, but its sources are in the hills, and occasionally it becomes a torrent. Unfortunately it has never been gaged, and ... its drainage area is not known; it is probable, however, that its discharge is at times as much as 3,... cu. ft. per second, and possibly much more.

The canal line as located crosses the Tola a short distance above its mouth, and the disposition of the flood waters has been considered a matter of some difficulty; this apprehension and the advantages which would result from the extension of the summit level toward the Pacific, with the formation of a wide basin in the valley of the Rio Grande, have led to the adoption by the company of the alternative "Tola Basin line."

At a place called La Flor, 3.8 miles from the Pacific terminus and 13.9 miles from the lake, the valley of the Rio Grande is narrowed by two steep hills to a width, on the valley floor, of 1,600 ft., at an elevation of 40 ft. above mean tide, and a width of 2,000 ft. between the summit-level contours of elevation 110. The company proposes to build a dam at this point of sufficient height to raise the water to elevation 110, thus extending the summit level, as already stated, to within 3.8 miles of the Pacific, forming a capacious basin of some 4,000 acres in the valleys of the Rio Grande and Tola. This arrangement would facilitate navigation by substituting a basin for 4.6 miles of canal, and would solve the question of the disposal of the flood waters of the Tola by permitting their free discharge into the basin.

As originally designed, the La Flor or Tola Dam, as it is indifferently known, was, like the Ochoa Dam, to be a "rock fill" and to be constructed in the same way, with a weir on the crest for the discharge of the Rio Grande drainage. This plan has been modified more recently by providing a solid concrete core for the dam, backed with a stone and earth embankment on both sides, and locating a weir in the saddle of an adjacent hill. This weir is to discharge the drainage of the valley and, as the Board is lately informed, about 66% of the surplus discharge of the lake watershed also. The question as to what disposition to make of the drainage during the construction of the dam or its masonry core has not yet been fully considered by the company.

The La Flor Dam, per se., is a much more formidable construction than that proposed at Ochoa, in regard both to its volume and the head of water it has to sustain. The river channel cuts about 20 ft. into the general surface of the valley, and the contour of elevation 20 ft. above mean tide crosses its bed immediately below the site of the dam. During the dry season the river runs dry, and the surface of the ground water is below the bed, as would be the case also below an impervious dam. It follows, therefore, that the head of water against the dam would be fully 90 ft. and it hardly need be said that only the best material is admissible for the foundation of a dam under such a pressure, and where such vast interests depend upon its integrity. The foundation should be solid rock, free from fissures or seams, or, at least, a core wall should be carried down into such material if accessible.

In 1892 and 1893 diamond-drill borings, 26 in number, were made along the center line of the dam and at several points within 400 ft. of it, with very discouraging results. A mass of sand, gravel, and mud was found on the center line extending 75 ft. below the floor of the valley, or 35 ft. below sea level; several borings passed through materials below this level, reported as "coarse sand," "yellow clay," "clay and rock in layers," "yellow clay and sandstone," etc., to depths reaching 150 ft. below sea, and among other borings taken was one 400 ft. above the center line and close to the area to be covered by the dam, in which the material, from 40 to 214 ft. below sea, was "clay, sand, and pieces of rock," followed by 30 ft. of "telpetate" (a soft, clayey, volcanic rock), and 54 ft. of "white clay with pieces of rock," and the boring was ended in this material, 298 ft. below mean tide, or 338 ft. below the surface of the ground, without having encountered any solid material.

If such are the facts, the Board deems the project of a 90-ft. dam impracticable, and omits consideration of its construction. It may be pointed out that, in any case, the advantages to be expected from the dam are no more than the substitution of 4.6 miles of basin for an equal length of plain canal and the disposal of the flood waters of the Tola, and these benefits are not of such magnitude or urgency as to justify an attempt to secure them at any such risk as the construction of the dam would involve.

It should be stated that the unfavorable results of the borings at La Flor are in part, at least, recognized by the company, which, nevertheless, is unwilling to abandon the plan of the dam and basin on the present evidence in the hope that additional borings may be more favorable. It is difficult to see what foundation there is for such a hope. The engineer who had charge of the borings was reputed to be, and his notes and report indicate strongly that he was, careful and competent, and the facts as observed and reported by him seem fatal to the plan. If the views of the Board are correct, a return must be made to the low-level plan—a canal in excavation and embankment. The only serious objection to the company's location of this relates to the disposal of the floods of the Tola. It would probably be necessary to receive this water into the canal and to discharge it over a weir at some convenient place on the opposite side, whence it would pass into the Rio Grande. The current in the canal caused by this flood would probably not exceed 1 ft. per sec., or seven-tenths of a mile per hour, but there is some uncertainty about this, as the Tola has not been gaged, and its maximum discharge is not known, and proper gagings may show that it is underestimated.

From examination of the topography the Board finds reason to believe that a canal line can be carried down the south side of the valley without any special difficulty, and so avoid all interference by the Tola. A map location indicates that the line will be shorter, and two or three diversions of the Rio Grande channel will keep the river entirely to the north of it. The cost is somewhat greater by reason of more excavations, but it may

be worth this to be free of the Tola discharge. Both locations should be thoroughly studied and selection made of the better. With present information the Board prefers the southern route, and its estimate is made for that.

If this modification were carried out it would be advisable to change the location of Lock No. 1 to a new site 500 ft. southward; to build a weir at the former lock site, to discharge the water of the upper Rio Grande, and to close the remainder of the valley, here quite narrow, by a dam at the west limit of the summit level; the head of water to be sustained by the dam would be only 20 ft.; it would be founded on the so-called "telpetate," and have to be sunk well into it to make the foundation secure, but with the moderate head of water no great difficulty would be met. As the flow of the upper Rio Grande must be taken into the canal at the head of the gorge the effect on navigation of the introduction of its floods must be considered.

The area of the company's standard canal section in earth is 5,896 sq. ft.; the flow of the stream at high floods has never been gaged, and is not known. It was estimated by Colonel Childs at 5,670 cu. ft. per sec., but this may be exceeded. If this amount of water were to pass westward through the canal it would produce a velocity of 1.5 per sec. If, on the other hand, no water were allowed to pass the weir at Lock No. 1 the river discharge would be compelled to find an outlet through the canal eastward into Lake Nicaragua, producing a current of 1.9 ft. per sec. or more in the divide cut, where the area of the cross section (in rock excavation) is 3,000 sq. ft. In that confined section this current would be undesirable; but it is evident that the weir at Lock No. 1 can be so regulated under intelligent supervision as to cause a division of the discharge of the river at the head of the gorge, part going westward to the Pacific, the remainder eastward to the lake, and the current in both sections limited to so low a rate as to be harmless.

The disposal of the water of the upper Rio Grande being thus provided for, it seems unnecessary to carry out the company's project of diverting it by an expensive dam across the upper valley and the construction of an artificial channel and embankment across the dividing ridge into the valley of the Lajas and thence into the lake. The company's proposition to discharge through the canal into the Pacific a large part or any part of the surplus water of the lake watershed would be objectionable for reasons above indicated; and, in general, the use of a canal as a drain should be avoided when practicable.

For the first 1¼ miles from the lake, where the canal line follows closely the general direction of the river Lajas, the average elevation of the ground is little above the proposed lake level. The company proposes to make this section 120 ft. wide at bottom, for use as an extension of the harbor and a passing place for vessels; but it appears to the Board, as in the case of the canal from Greytown, that this width is insufficient for the meeting of two vessels and more than necessary for the movement of one. If a suitable passing place were formed at the west end of this section, long enough to receive three or four vessels, and the bottom width eastward to the harbor reduced to 100 ft., the cube of excavation would not be changed materially, while the work would serve the purpose better.

The material from the western crossing of the river Lajas to the eastern crossing of the Rio Grande, a distance of 6 miles, covering the west divide, is principally volcanic rock, of all degrees of hardness, from "telpetate" to the so-called "conglomerate." In a frosty climate "telpetate" would disintegrate rapidly; even in the mild climate of Nicaragua it is found more or less disintegrated wherever exposed. Conglomerate is usually hard rock resembling trap, and while its excavation would be more expensive, the sides of a cut formed through it would be more permanent. Borings—19 in number—have been taken with a diamond drill, at intervals of about 1,000 ft., through the heaviest work; after passing through earth of an average depth of 12 ft., rock was reached and penetrated to the grade of canal bottom. The cores obtained by the use of the diamond drill would have been valuable if preserved and properly arranged, furnishing a complete record of the material passed through, but only a few of them, representing the harder rock traversed, are now to be had. Many cores were left on the ground, where fragments are still to be found, showing much disintegration.

The company's standard canal cross section, in rock, has vertical sides from the bottom to 10 ft. above water, where there is a berm of 5 ft.; above this the slope is 1 horizontal to 5 vertical. Considering the nature of the rock, it seems probable that these slopes can not be maintained throughout the cut, and in such case the amount of excavation will be greater than estimated, but in the absence of more definite information there is no means of providing for what may prove to be the necessary increase except by a more liberal allowance for contingencies.

In the estimate of 1890 the company assumed that all of the locks of the western division would be founded on rock, but borings made in 1892, at the site of the tide lock, showed a deposit of mud of unknown depth extending at least 37 ft. below lock bottom, and in the estimates of 1895 an additional sum of $250,000 is entered for foundations. A less difficult site can without doubt be found. At the site of the second lock from the lake, on the low-level line, no borings have been taken except with an earth auger, and the existence of rock at the elevation reported is doubtful. Rock of some kind has been found at the remaining sites on both lines.

It is believed by the Board that the arrangement of locks proposed by the company, which gives the summit lock a lift of 25 ft., while the tide lock has a lift of 29½ ft., should be changed. In locking down to the sea level certain disturbances caused by difference in specific gravity of salt and fresh water will delay the operation of the tide lock, and it will be judicious to reduce its lift. The Board, therefore, would modify the project to give this lock a lift of 24½ ft. at mean low tide, the three others having 30 ft. each. There results a considerable increase of excavation in all the levels between the summit and tide locks, the cost of which is believed to be justified by the increased efficiency gained.

The company, for some reason not stated, has left the depth in the canal between the tide lock and Brito Harbor at 28 ft., although the canal above the lock and Brito Harbor itself are to be excavated to 30 ft. The exception made is inexpedient, and the full depth should be made continuous and provided for in the estimates. The Board's estimates include this.

It is proposed to place a guard gate in the divide cut to shut off the water of the lake, should it be desired at any time to draw the levels to the westward. There are no detail drawings or computations for the gate, and the company's estimate of its cost is entered in the schedule.

BRITO HARBOR.

The report discusses the projects of Childs, Lull, Mitchell and the canal company for this work in much detail. The company's project is criticised on the ground that the protection in the way of breakwater was so planned that the harbor would be subjected to a heavy sea swell, and no provision was made for the removal of a submerged reef, which extended out nearly to the middle of the harbor and directly opposite the entrance. The Board states that the data collected by the company were too few to permit of any really safe estimate of cost or to settle the question of satisfactory location. The Board makes, however, various suggestions of charges for this work, and while the company allowed $1,920,961 for Brito Harbor, the Board makes a provisional estimate of $4,398,500 as its cost.

GENERAL CONCLUSIONS.

All locks should have a width of not less than 80 ft. if the navigation be intended to provide for the passage of war vessels and for future developments in the case of commercial vessels. The U. S. S. "Iowa" and others of the same class have a beam of 72 ft., 3 ins., and still others are now contemplated with a beam of 75 ft.

All streams affecting the canal route should be gaged to ascertain their regimen, and in particular the regimen of the lake and the San Juan and San Carlos rivers should be carefully determined.

Rainfall observations should be made at several consecutive points over the entire route from Greytown to Brito.

The construction of the eastern division on the line proposed by the company is feasible, but in view of the risks involved in the maintenance of the numerous dams and embankments the final adoption of any route is inexpedient until all alternative routes shall have been fully investigated and compared.

Full explorations for alternate routes in the eastern division should include the so-called low-level line on the left bank of the San Juan to the San Juanillo and thence to Greytown; and, more particularly, full investigation should be made as to the practicability of extending the canalization of the river to the vicinity of the Serapiqui by means of comparatively low dams.

The cost of work, particularly in the eastern division, will be increased in consequence of the heavy rainfall, but from observations made, its destructive effect on completed work will be much less than that of frost in the United States.

The climate of Nicaragua is mild, equable, and humid, and while the sanitary conditions are not unfavorable as compared with portions of the United States, the value of physical labor is much less. It is probably to be expected that the opening of earth excavations will be attended, as elsewhere, by the development of malarial diseases, but not of a specially malignant type.

The volcanic and seismic forces in Nicaragua are manifestly declining, and there seems little reason to apprehend disturbance of so serious a character as to imperil the stability of canal construction.

The official estimate by the company of $66,466,880 is insufficient for the work. In several important cases the quantities must be greatly increased, and in numerous cases the unit prices do not make proper allowance for the difference in cost of work between the United States and Nicaragua.

The provisional estimate by the Board is $133,472,803. It should be understood that the existing data are inadequate as a basis for estimating the cost of many of the structures; some portions of the work may cost more, others less, but in the judgment of the Board the entire project can be executed for about the total amount of its estimate.

For obtaining the necessary data for the formation of a final project, eighteen months' time, covering two dry seasons and an expenditure of $350,000, will be required.

COST OF WORK AND ESTIMATES.

Climatic and Labor Conditions.

Before fixing unit prices for an estimate of cost of the canal, the Board has examined with much care a large amount of data relating to cost of similar work in the United States. Several contractors of high reputation in their respective lines have examined the maps and plans, and have aided the Board by furnishing estimates of costs of various classes of work. Several gentlemen of wide experience in the execution of work in the Tropics have also given information of great value.

It can not be expected that work can be done in Nicaragua at prices ruling in the United States. The first cause of this, which will readily appear to anyone, is the climate.

Another cause for higher cost of work in Central America is the comparatively ineffective manual labor which has to be relied upon. The natives of Nicaragua are not likely to prove useful laborers in the severe and steady work of canal construction. Negroes from the West Indies, principally from Jamaica, have been employed largely at Panama and on the Costa Rica Railway. Under good management they are docile and from a tropical standpoint are considered industrious and fairly effective. They will undoubtedly form the labor supply for the canal. Wages are only about one-half as much as in the United States, but the efficiency of the laborers is much less in proportion.

There is a marked concurrence in opinion of those who have had experience in the management of construction work in Central America that the cost of work, due to inefficient labor and unfavorable location and climate, is about twice as much as in the United States.

Machinery will be used largely, but will be of little value after completion of the canal, and hardly any of it will be worth removal; its entire cost would, therefore, be charged to canal construction, making the plant charge higher than usual. Repairs of plant will be expensive. There are now no shops or facilities of any kind on or near the canal line, and they will have to be supplied as adjuncts of the work.

There is no skilled labor in the country, and it will have to be imported at rates of wages much higher than prevail here. Extra men will have to be kept on hand, transportation to and from the United States will have to be paid, and it may be said that the expenditure on account of pay rolls and traveling expenses will be twice as much as in the United States. Fuel will cost more than double. Freight on materials and supplies will increase their cost greatly, particularly if sent to interior points.

It appears therefore that the rule applied to manual labor will hold good also as to work done by machinery, and in general the cost will be doubled. On the Atlantic Coast, the factor should be somewhat greater than two; on the Pacific Coast, somewhat less.

So far as shown by experience, the sanitary conditions in Nicaragua are favorable. During the building of the railroad across the swamps from Greytown westward the health record of the men, who were mostly Jamaica negroes, was very good, although they were constantly in the water.

When deep excavations are made in the clay there may be a different result. The Jamaicans, however, suffered little when employed in the construction of the Costa Rica Railroad, where the cuts through the hills were very heavy, and it is believed that with these or other acclimated laborers, under complete police control and subjected to judicious sanitary regulations, there will be no more sickness than occurs on public works in many parts of the United States.

Unit Prices.

Dredging.

Greytown Harbor.—Material, coarse volcanic sand of light specific gravity. It will have to be deposited outside the harbor lines, either in the swamps or at sea. There will be some exposure to the sea in the harbor entrance. The interior dredging can be done for 20 cts.; in the entrance, 40 cts.; average price used in the estimate for the entire amount, 25 cts. per cu. yd.

Greytown Harbor to Lock No. 1.—Material, sand for one-third of the distance; then mud and clay. From the west end the tow will be long, if material is taken to sea; if deposited on bank by a pump or ejector the lift will be about 20 ft., plus height of spoil bank. Estimate price, 25 cts. per cu. yd.

San Juan River.—Material, according to Lull's classification, made from lead-line indications, is clay, sand and gravel. A large amount of material classified by him as rock is believed to be gravel and bowlders and is so taken in the estimate. A large part of the material will have to be delivered on river bank to avoid reducing channel area. On account of this, and the uncertainty as to the nature of the material, the unit price in the estimate is increased to 30 cts. per cu. yd.

Lake Nicaragua.—Material, mud and clay. The quantity is large and the situation sheltered. The clay can be dumped within a short distance; the mud can be pumped to a sufficient distance to insure against running back into the cut. Estimate price, 20 cts. per cu. yd.

Brito Harbor.—Material and conditions similar to those at Greytown Harbor, and same unit price used—25 cts. per cu. yd.

Earth Excavation.

Eastern Division.—Material, stiff clay. At the Chicago drainage canal, excavation of hard clay with steam shovel costs 22 to 25 cts. per cu. yd. where the ground is level and plant for dumping can be moved easily; the work there is done in the main when the ground is dry. In the heavy rainfall region of eastern Nicaragua the material will become difficult to handle; the lock pits will be deep and will require some pumping; the canal line between locks is crossed several times by the Deseado, which will have to be diverted, and cost charged to excavation. In the east divide and beyond to Ochoa the country is made up of steep hills, where it will be difficult to work plant to advantage. Estimate price, 60 cts. per cu. yd.

San Carlos Embankment line.—Material, clay. Excavation is made to remove surface soil at sites of embankments; therefore of small depth, usually of small area; material to be dumped just outside of excavation. Estimate price, 50 cts. per cu. yd.

San Juan River.—Material, probably clay. Excavation required to straighten channel. Rainfall becomes less going west. Estimate price, 50 cts. per cu. yd.

Western Division.—Material, light loam, sand, and clay. Rainfall less, and country less hilly. Estimate price, 40 cts. per cu. yd.

Rock Excavation.

Eastern Division.—Material all degrees of hardness from telpetate to trap; of volcanic origin and not stratified. The harder rock will not drill and blast nearly as well as the rock in the Chicago Drainage Canal, where the contract price is about 70 cts. It will not drill or break better than the gneiss about New York city, which costs for excavation about 80 cts. The telpetate is softer, but it may prove impossible to maintain it vertical or with slope of 1 : 5, as proposed by the company. The country is a mass of hills, and plant cannot be handled as readily or employed as usefully as in a level district. The heavy rainfall will increase cost of work. Estimate price, $1.75 per cu. yd.

Western Division.—Material, similar to that in eastern division, but with less hilly ground and better climate; the Board assumes the unit price at $1.25 per cu. yd.

Mud Excavation.

Eastern Division.—East of divide small quantities of moderate depth are to be removed from embankment sites; estimate price, $1 per cu. yd. West of divide at sites of several embankments mud is to be excavated to depth of 30 ft. or more. Cost of protecting sides of cut by crib work or other means to prevent slides into cut will be large, and is included in the estimate price of $1.50 per cu. yd.

Embankment.

Greytown Harbor to East Divide.—Material, clay. To be placed on cars when excavated from lock or canal prism. Embankment price covers cost of transportation, taking from cars, placing in embankment, and rolling or tamping. Company's price used in estimate, 30 cts per cu. yd.

East Divide to Ochoa.—Material, clay. About half will have to be borrowed. Estimate price, 45 cts. per cu. yd., which allows 30 cts. for excavating one-half of the material from pits favorably located.

San Carlos Ridge Line.—Material, clay. All will have to be borrowed. Embankments are generally small, at considerable distance apart. An excavation price of 40 cts. is added to an embankment price of 30 cts., making the price used in the estimate 70 cts. per cu. yd.

Back Filling Behind Lock Walls.

Eastern Division.—Material, clay. In most cases to be excavated from side of lock pit to lighten bank. Locks

generally located in hills. If quantity is insufficient, deficiency is to be made up by borrowing. Excavation price 40 cts. added to embankment price of 30 cts., making 70 cts. per cu. yd.

Western Division.—On account of material being more easily handled and more favorable climate the price is reduced in the estimate to 60 cts. per cu. yd.

Materials for Ochoa Dam.

Rock Fill.—Material to be principally in pieces weighing 4 to 10 tons, obtained from east divide. A sufficient amount cannot be obtained by ordinary blasting, therefore quarry methods will be required, adding to cost of excavation.

	Per cu. yd.
Additional cost of excavation is estimated at.....	$0.50
Transportation to dam (1 ct. per ton-mile).....	.30
Handling at dam.....	.20
A large amount will have to be stored for final season's work, involving two handlings; cost of this distributed over whole amount.....	.15
Cost per cu. yd., solid.....	$1.15

One cu. yd. solid makes 1.7 cu. yds. loose. Cost of 1 cu. yd. loose, 68 cts., say, 70 cts. for estimate price.

Earth Fill.—Material, small stone and clay. Waste from east divide:

	Per cu. yd.
Transportation.....	$0.30
Handling at dam.....	.20
Estimate price.....	.50

Submarine Rock Excavation.

San Juan at Toro and Castillo Rapids and at Canal Entrance West Side of Lake.—Material, probably hard, volcanic rock, without stratification except on west side of lake; latter amount relatively small. Work will be done with expensive plant and skilled labor; plant should be charged to work. Present contract price for limestone, hard but horizontally stratified, drilling and blasting well, in the St. Marys River, Michigan, $2.43 per cu. yd. In Nicaragua cost of plant will be 50% greater, pay roll will be double, cost of repairs and fuel more than double. Estimate price, $5.

Sheet Piling.

The unit prices in the company's estimate, which provide for creosoted timber, are accepted by the Board.

Stone for Breakwaters.

Greytown and Brito.—Stone from divide cuts. Stone to be received on cars at points where excavated. Cost of transporting and depositing in breakwaters, including necessary trestle, will not, it is believed, exceed the estimate price of $1.50 per cubic yard. The trestle will be a temporary pile bridge; storms seldom occur, and cost of trestle will not be great.

Concrete for Locks, Sluices and Weirs.

Eastern Division.—Greater part of work from 12 to 17 miles from Caribbean; a few small works 22 to 28 miles; cement, Portland, delivered by ship at Greytown; sand from Greytown beach; stone from east divide cut. Proportions suggested by company: Cement, 1; sand, 2; stone, 5 by volume. Concrete for lock construction with these proportions costs $9 per cubic yard, including timber forms, at the Hennepin Canal, 1893. With proportions of 1 : 2 : 3 for face and 1 : 3 : 6 for backing, the cost can be reduced and satisfactory structures obtained.

A careful, detailed estimate has been made, and $9.50 adopted as the estimate price.

San Carlos Sluices and Weirs.—Transportation of materials to site will be more expensive than for eastern division, and the estimate price is made $10.

Western Division.—Cement will cost a little more than on the eastern division, by reason of higher freight charges. Cost of sand from the beach at Brito and stone from the west divide will be less than sand and stone in eastern division, on account of better climate; cost of mixing and placing will be less; these reductions will more than offset the greater cost of cement. Estimate price, $9 per cu. yd.

Metal Work.

Lock Gates.—The contract price for the steel gates just built for St. Marys Falls Canal was 7 cts. per lb. Material will probably come from Europe at less than first cost in the United States. Erection in Nicaragua will cost more than here, and the final cost is taken the same as here, at 7 cts. per lb.

Gate Anchors.—Contract price at St. Marys Falls Canal is 3.77 cts. per lb.; estimated price, 4 cts. per lb.

Steel in Foundations.—Material to come from Europe. Field riveting small in amount. Estimate price, 3 cts. per lb.

Steel in Culverts.—Material from Europe. Field riveting and calking expensive in Nicaragua. Price for estimate, 4 cts. per lb.

Gates and Machinery for Sluices.—The prices taken by the Board are makers' prices, with an allowance for transportation. The company's estimate appears to be made for only one-half the number of gates intended.

Sluices and Weirs.

Eastern Division.—The company's estimate provides two sluice openings 20 ft. by 25 ft. and 200 lin. ft. of weir at each lock, and equal amounts of both in the San Francisco embankment line. For the purpose of entering the items in the estimate, the Board assumes the same provision.

San Carlos Embankment Line.—The price estimated provides for 4,000 ft. linear of weir, instead of 1,200 ft., as in the company's estimate. No change is made in the number of sluices. These quantities, which may have to be changed after further surveys, are assumed only to take the items into account.

Railways.

Eastern Division.—The estimate of $100,000 per mile is believed sufficient for a double-track standard-gage railroad. The country is hilly, the grading will be heavy and there will be considerable pile bridging and trestling; but there will probably be no rock cuts. The amounts added for buildings, etc., are sufficient for the temporary buildings suitable for a construction line.

Western Division.—With a low-level canal there will be no difficulty locating a railroad with light work and easy grades and curves, excepting the 1½ miles through the gorge of the Rio Grande. Estimate price, $50,000 per mile for a double-track standard-gage railroad.

Miscellaneous.

The Board has adopted the company's figures in many cases for minor structures, and in a few cases for important ones, where it was impossible to check them with the limited time and means at its disposal. The most important of these structures are the weirs and guard gates. As to the weirs, their dimensions are subject to change after the ascertainment of the duty required of them, and changes in their dimensions, if in the way of increase, must at this stage be considered as an item of contingencies. As to the guard gates, there are no plans, but the amount estimated for them by the company may possibly prove sufficient.

The company's estimate contains amounts for receiving basins for several creeks taken into the canal, for fender work in the approaches to the locks, and for a few other small items. The Board has entered the amounts in its estimates without analyzing them minutely; any errors in amount will be relatively unimportant.

In the absence of any data on the subject the Board has not endeavored to make any estimate as to the damages to be incurred from submergence of lands in lake and river valleys.

Management and Engineering.

Cost of management and engineering is estimated at 4% of the cost of construction.

Hospital Service.

Adequate hospital service is of prime importance for the successful prosecution of the work. It would not be judicious to leave this to the control of the large number of contractors who would be employed, as they would not be likely to agree on effective measures, and lack of vigilance at any point might start a disastrous epidemic. For these reasons the canal company should assume the responsibility, and organize a hospital service on a liberal scale. An item of $1,000,000 is inserted in the estimate for this purpose.

Contingencies.

The allowance for contingencies is intended to cover those items of increase due to unforeseen emergencies and exigencies as to climate and imperfect information as to the extent and character of the work; in the present case, these uncertainties are unusually large, and in the judgment of the Board the allowance of 20% is the least admissible.

Quantities.

The quantities of excavation and embankment carried in the estimate are based on the company's maps and profiles, and in most cases, unless otherwise stated in the report, its calculations of amounts are accepted. The Board has verified them approximately, and believes the maps and profiles on which they are based to be substantially correct.

RIVER REGULATION BY SUSPENDED FASCINES IN BAVARIA.

By Henry M. Melchers, C. E.

The regulation of rivers is a department of engineering which has been carried out on a larger scale in the United States, probably, than in any other country of the world. But while no streams which European engineers have attempted to control approach in volume the Mississippi and its great tributaries, it is also true that in the regulation and control of the smaller rivers, much more has been done in Europe than in America. In the countries of central Europe where population is dense and land is dear, the regulation of water-courses is an important field of engineering work.

In regulating the channel of the lower portion of the River Isar, a typical mountain stream in Bavaria, Germany, it became necessary to abandon the ordinary methods of regulation by wing-dams, mattresses, etc., and devise a new system consisting of horizontal planes of fascines, which are suspended above the river bed by means of piles or a system of pile frames. This construction admits of the detritus passing unobstructed through such "works of attack," but is deposited beyond them through the check given to the current velocity by the suspended facine.

The credit for the invention of this system is due to Mr. Wolf, of Landshut, Bavaria, who is the engineer in charge of the work on the River Isar, in the province of Lower Bavaria.

The Isar, as mentioned above, is a mountain stream, and has a minimum water flow of 90 cu. m. per second, an average maximum water flow of 600 cu. m. per second, and carries an immense quantity of detritus. The average current velocity varies from 1.50 to 2.50 meters per second.

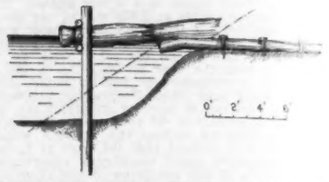

Fig. 4.—Protection of Natural Embankments by Fascine Mattresses after High Water Period. (Second Stage of Works Shown in Figs. 1 and 2.)

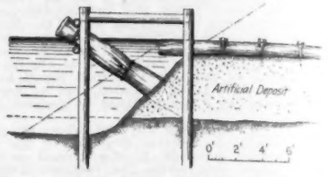

Fig. 5.—Method of Protecting Artificial Deposits.

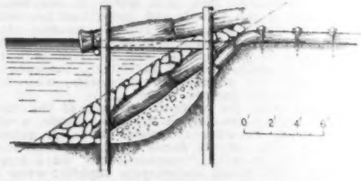

Fig. 6.—Third Stage of Works. Completion of Bank Slope

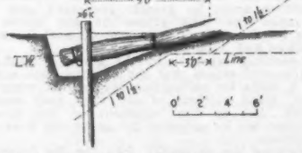

Fig. 1.—Formation of Channel through Low Land.

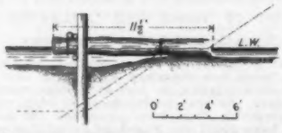

Fig. 2.—Formation of Channel through Shallow Water.

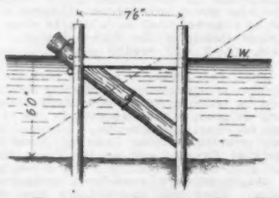

Fig. 3.—Formation of Channel in Deep Water.

THE USE OF SUSPENDED FASCINES FOR RIVER REGULATION ON THE RIVER ISAR IN BAVARIA.

In carrying out the regulation works according to the system of Mr. Wolf, there are four stages of operation. The first step is the reduction of the river to a standard cross-section* and the filling up of abandoned portions of the channel.

*The standard cross-section of any river may be found in those "straight portions" of the river course where the river bed and the river valley are neither too narrow or too broad. Where, also, the soil of the embankments and the river bed is firm enough to withstand the erosion of the water, and therefore neither washing of the banks nor deposits take place. Where the above conditions are fulfilled in a greater stretch of river course, there also the "normal fall" of the river is found

The second step is preparing for revetments and the holding fast of artificial deposits. The third is the completion of the earth-work and the revetment of the bank slope to conform to the standard cross-section. The final step is the completion of the bank filling above high-water mark and of parallel works, where such are necessary.

Figs. 1, 2 and 3, herewith, illustrate the application of the suspended mattress system to the first stage of operations. In Fig. 1 a channel is to be made through low flat lands. A trench about 12 ft. wide is first dug along the proposed line of the channel and piles are driven along it at intervals of about 7 ft. To each pile at low-water mark one end of a fascine about 12 ft. long is fastened, the other end resting on the side of the trench which is later to form the permanent bank of the rectified stream. It will be understood that most of the work of excavation is done at high water, the force of which deepens the trench and widens it on the left-hand side in the figure, while the material is largely deposited between and beyond the fascines.

Fig. 2 illustrates the method used where a channel is to be made through shallow water. As before, deepening occurs beneath and to the left of

the fascines, while the shallows to their right are filled with deposits. In Fig. 3 the same system is applied to deeper waters, in the case of the Isar from 13 to 16 ft. Here a pile frame is built, either two or three rows being driven, according to circumstances. The fascines are secured to the piles in such a manner as to allow of a slight pendulous movement, thus forming a sort of elastic wall. The irregularities of the current volume will raise or lower the planes of fascines, the movement of which

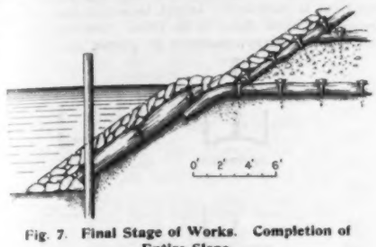

Fig. 7. Final Stage of Works. Completion of Entire Slope.

tends to equalize the opposing forces, and also to bring about a more gradual deposit of the detritus. It must be remembered that in this method we are to work with the waters and not in opposition to them.

The fascine works illustrated in Figs. 1 and 2 protect the natural embankment or artificial deposit behind or below it; and, also, in conjunction with a proper form of construction on the opposite bank brings about a concentration of the water flow, whereby the new river bed or channel

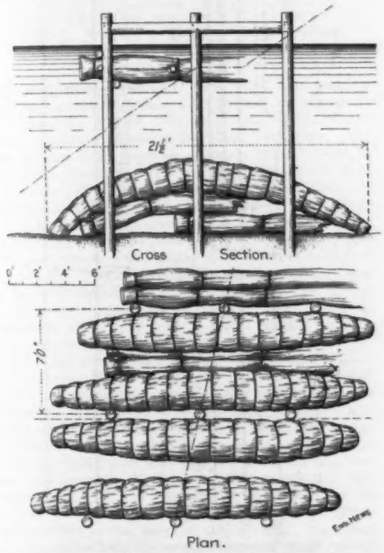

Fig. 8.—The Use of Suspended and Submerged Fascines in Combination.

will be deepened, until it attains its normal depth and cross-section. Furthermore, in addition to the foregoing, the construction in Fig. 2 also effects a deposit of the detritus, especially when the planes of fascines are so arranged as to leave small interstices between the individual bundles of fascines.

The construction in Fig. 3 is designed to bring about a deposit of drift behind the works to their full height. They also divert the stream in such a direction, as intended in the plan of work, as also to cause a concentration of the water flow.

Fig. 4 illustrates the second stage of operations in the case of the works shown in Figs. 1 and 2. It will be seen that the artificial deposit at the right of the channel is now protected by a fascine matting. The piles and suspended fascines have proved to be quite efficient to prevent erosion of the new bank by the current.

In Fig. 5 the method of protection of artificial deposits formed back of the pile frame in Fig. 3 is illustrated.

The third stage of work, or the completion of the earth-work and revetment of bank slopes, is shown in Fig. 6. Of course this is merely a typical illustration. The material available for filling and other local conditions, will necessitate considerable variations. Fig. 7 shows the final stage of the work, which also varies greatly, according to local conditions.

The experiences gained with this system from the years 1884 to 1890, proved to Mr. Wolf that in some particular instances the working of this method, as described in the foregoing, was not efficient to the extent desired (both as to time required and work achieved), and it also gave at times just cause for alarm to the engineer in charge. A thorough study into the causes of such failure led him to the use, in addition to the suspended fascines, of submerged fascines, as illustrated in Fig. 8, which do not in any way obviate the principles and working of the suspended fascines as laid down primarily—that is, of allowing the detritus to pass undisturbedly through the "works of attack" and behind the same, there to be deposited. He also succeeded in pointing out exactly when and where the water fascines must be put to use, in combination with the suspended fascines; one instance being illustrated in Fig. 9, where a protruding embankment, A, is to be removed.

On account of the increased velocity due to the concentration of the water flow, the current here has a tendency to undermine the piles or pile frames, possibly pulling them asunder, when the river will readily return to its old course, and the portion of the river to be abandoned, instead of being filled up, will be deepened, while the embankment will remain unmolested. But this can be prevented by using submerged fascines, placed as shown in Fig. 12, which illustrates this particular case. A second instance is shown in Fig. 10, where the line of direction of the water flow and the line of direction of the works of attack form an angle of nearly 90°, being at the upper end of a through-cut, for instance. (When the two lines of direction form a small acute angle the water-fascines are, in most cases, unnecessary.) Here, also, the water-fascines must be used, as also a three-pile frame, to successfully withstand the attack of the waters. The third instance where these constructions should be used is where very broad reaches of a river course are to be narrowed by fascine works on either side. Here also the water-fascines in combination with the suspended fascines avert the danger of the stream breaking through sideways, producing small side streams. These latter, under favorable circumstances, assisted by small banks of detritus, which will be deposited in the heart of the channel just below such a breakage, may cause the main stream to be suddenly thrown out of the intended course. The three cases above cited cover in a general way all other similar conditions, and in all of them it is therefore recommended to use a combination of suspended and water fascines.

The method employed to place the submerged fascines in position on the river bed is as follows: One or two planes of fascines, as required, are placed and fastened, as usual, in a horizontal position; upon them at either end submerged fascines are placed in their proper position (see drawings), whereupon the whole is cut loose from the piles and sunk. The planes of suspended fascines, which are now

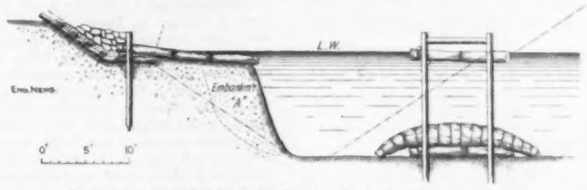

FIG. 11.— CROSS-SECTION OF WORKS SHOWN IN FIG. 9.

placed above as at first, ought not to be in an inclined position, but horizontal, or nearly so.

The high water will cause a side movement of the detritus as long as there are portions of the river bed to be filled up. In mean low water the detritus will be carried along the channel with the current. A still greater concentration of the waterflow, if desirable, can be achieved by temporarily fastening a single course of planks or timbers lengthwise above the planes of fascines from pile to pile.

In May, 1892, a party of professors and students of the Technical University of Munich, including the writer, had the pleasure of visiting the works of regulation on the lower course of the River Isar, under the guidance of Mr. Wolf.

We floated down the entire distance from Moosburg to Deggendorf (on the Danube), in a flat-bottomed boat, manned by three sturdy Bavarians. The whole distance, 53 miles of river course, was traveled in 16 hours, not including stops. From Mr. Wolf I gained the following data: Work by this method officially began in 1886, and in May, 1892, had attained a total length of operation of 36 miles, 28½ of which fall within the district under the personal supervision of Mr. Wolf. This portion, begun in 1886, was practically completed, and Mr. Wolf estimates that those portions begun in 1890 will be completed in 1896. This gives a total of ten years for the complete regulation and correction of 36 miles of river course.

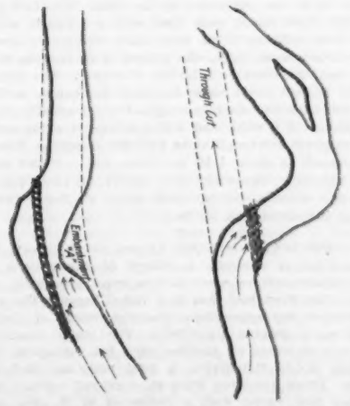

Fig. 9.—Use of Submerged Fascines in Rectifying Channel.

Fig. 10.—Use of Submerged Fascines in Filling a Bend.

THE SIPHON UNDER THE SEINE, at the Place de la Concorde in Paris, is thus described in "Le Genie Civil." Its purpose is to tap the present drainage system of Paris on the left bank of the river and convey the sewage under the river and into the Assinieres main collector on the right bank. It is a tube, 5.86 ft. in inside diameter, made of four flanged plates and a filling piece at the crown, with a total length of 776 ft. and a bottom depth of 37 ft. below the mean level of the river. The soil is very favorable in tunneling; but a shield was used in advancing the tunnel and compressed air was employed for the purpose of keeping out the water. The contracting engineer is M. Berlier, who lately completed the Clichy siphon, lower down the Seine. He obtained the contract for both siphons at his own risk and under a forfeit of $200,000 for the Clichy, and $95,000 for the Concorde tunnel. The Clinchy tunnel was 7.5 ft. in diameter and cost $122.70 per lin. ft. complete. The work was pushed from a single shaft, 10 ft. in diameter, on the left bank. The tunnel is nearly completed; the shaft having been sunk 49 ft. deep in 47 days, and the tunnel was finished in 111 days, a mean daily advance of 7 ft. The soil penetrated was, for about half the distance, calcarious strata alternating with grey marl. Beyond this point the tunnel penetrated blocks of calareous rock containing much water between them, and this 65 ft. was the most troublesome and costly part of the line. Near the right bank of the river the roof of the tunnel came within 11.7 ft. of the bed of the river and great precautions had to be taken to avoid an inrush of water. The tube is lined with concrete to the level of the interior flanges and arrangements are made to flush the tunnel by passing through it a wooden ball, after the manner employed in cleaning other siphons in Paris. The shield used is of the usual type, advanced by hydraulic rams abutting upon the metal ring.

A REMARKABLE FRACTURE OF CAST-IRON.

We illustrate herewith one of the most remarkable cases of fracture of an iron casting that has ever been brought to our attention. The casting was a mullion made for use in the Siegel-Cooper building now under construction at the corner of 19th St. and 6th Ave., New York city. It was lying on the floor of the building in the position shown in the sketch, Fig. 1, so that its upturned flanges formed a sort of trough. During a storm this trough filled with water, which was afterward frozen solid, and a portion of the outer ⅞-in. flange 51 ins. long was forced out, taking the shape of an almost perfect arc, as shown in the detail drawing, Fig. 2. The broken piece remains tightly wedged in between the uninjured portions of the flange. The fracture is almost a perfectly straight line, and it is in line with the slight recess cut on the face of the mullion for the bead which surrounds the depressed panel, the reverse of which is shown in the sketch, Fig. 1, and also in the rear elevation, Fig. 2. Actual measurement showed that the fractured piece was forced out in the center 2¼ ins. The immediate cause of the fracture was, of course, the freezing of the water contained in the trough, but the permanent elongation of the piece forced out, shown by its taking the shape of an arc and being tightly wedged at the ends can scarcely be entirely due to the freezing. It would appear that the section which broke away must have been under an initial compression, so that it sprung out when cracked away by the expansion of the ice.

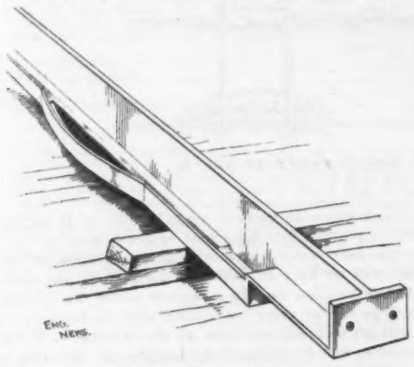

Fig. 1.—Sketch of Mullion Fractured by Freezing Water.

A CHART OF THE ARCTIC REGION is soon to be issued by the Naval Hydrographic Office. It is to show the results of the latest surveys with the investigations of various nations given in inks of different colors. It is described as being very complete in mapping the work done in this region, and as being a magnificent piece of lithography. It will be ready for issue in about one month and will be on sale at a price simply covering its cost.

NEW YORK STATE MAPS, made under the direction of Mr. Charles D. Walcott, Director of the U. S. Geological Survey, and Mr. C. W. Adams, State Engineer and Surveyor of New York, have been lately issued for the following sections of the State: Oneida, Pulaski, Chittenango, Amsterdam, Oriskany, Fort Ann, Cambridge, Mooers and Whitehall. Each of these sheets show the topography and contours, with 20 ft. intervals, for a section of country about the towns named and over an area of about 200 sq. miles. The scale adopted is 1 inch to the mile. They supplement previous similar sheets already issued for other sections of the State.

A COLLEGE OF ARCHITECTURE will be established at Cornell University, with a four years' course of study. The successful graduate would be entitled to the degree of Bachelor of Architecture. Mr. Raymond F. Almirall will co-operate with Prof. Osborne, of the present Department of Architecture, in formulating a plan of study, to be based upon that pursued in the Paris School of Fine Arts. The course will include mathematical studies, construction, detailed knowledge of the architectural orders, drawing from life and the antique, and modeling. The last two years will be devoted to the making of designs, specifications, etc.

THE BRAZELLE ALUMINUM PROCESS, which the American Aluminum Co., of St. Louis, has been experimenting with at its works at Fairlawn, Mo., is still doing more promising than performing. The directors of the company, on March 9, issued a printed circular to the stockholders, asking them to subscribe to 3,000 more shares of the stock, at $5 per share, the proceeds to be used for purchasing a new gasholder, for strengthening the refining furnace and for other necessary changes. The manager's report is also printed, recounting some of the troubles he has had with the apparatus, which have prevented his making aluminum on a commercial scale, and asking for an increased contribution of money from the stockholders. He is just as sure as he was originally that the process will ultimately be successful, but the stockholders apparently are not quite so sure.

THE EXTENT OF THE MINING BOOM in Colorado is illustrated by a "Mining Stock Manual," issued by a firm of brokers in Denver, which gives a list of about 600 new mining companies incorporated to transact business in Colorado during 1895, up to Dec. 17. The aggregate capital of these companies is about $300,000,000. On Jan. 2, 1895, there were 17 Cripple Creek mining stocks listed on Colorado exchanges, the aggregate capital being $25,150,000. The average market value of the shares on Jan. 2 was 7.53% of par, or about $1,900,000, and on Dec. 1, 31.28%, or $7,900,000, showing a profit to holders, based on the increase in market value of 315% on their investment, or about $6,000,000. What dividends were declared is not stated. It is safe to predict that the 600 new companies incorporated in 1895 will not give a profit to their stockholders of 315% in 1896.

THE UTAH ASPHALT BEDS, in the Uncompahgre Reservation, lately called forth some spicy debate in the U. S. Senate. Senator Cannon, of Utah, advocated a resolution making it compulsory upon the Secretary of the Interior to throw open to public entry all lands in this reservation not taken up by Indian allotments. The territory thus opened to settlers would include about 2,000,000 acres. Other Senators called attention to the asphalt deposit on this reservation as being probably the largest and finest in the world, and while this deposit should be opened to commerce, they argued that the government should draw some benefit from it, as well as the asphalt companies whose agents were ready to stake out claims as soon as authorized. The Secretary favored putting up these lands at auction and selling them to the highest bidder. The charge that this plan would debar the poor man from joining in the profits, was met by the counter-charge that all deposits of value were well known and were now practically under the hands of the capitalists. Senator Vilas proposed to reserve lands containing asphalt, gilsonite or like substances for further action by Congress. Action on the matter was postponed.

ELECTRO-PLATING A SHIP'S BOTTOM to prevent corrosion and the accumulation of barnacles has recently been tried at Jersey City on the iron tugboat "Assistance." In the process the copper was deposited from baths about 5 ft. square and 18 in. deep, shaped so as to fit the curvature of the hull. The baths were applied three times, each time with a different solution. The first solution is an acid, used simply for cleaning the surface from oxide, the second is of cyanide of copper, and the third of sulphate of copper. The first two baths remain on the vessel for about 24 hours each, and the last bath four days or longer. For the cyanide solution a current of 6 volts and 900 amperes is used, and for the sulphate solution 3 volts and 900 amperes. The copper deposit is about 1-16 in. thick, and perfectly smooth and regular. The baths are placed in such positions that the deposits overlap each other on the edges, insuring the absence of joints.

A NEW WAVE MOTOR, known as the Gerlach, is being tried at Capitola, a suburb of Santa Cruz, Cal. Two experiments on wave motors were made some years ago in San Francisco, but they failed because the waves demolished the apparatus. The experiment at Capitola is of much greater magnitude. The motor consists of two sets of vanes or paddles, each set containing three paddles, 9×12 ft., giving a total resisting surface of 648 ft. These are hung from an overhead vertical shaft, so that they swing with a radius of 32 ft., the maximum chord described being 12 ft., and averaging 7 to 8 ft. A double swing of each set of paddles is said to be made eight times per minute, making 32 single swings per minute for the two sets. The motion of the paddles is conveyed by chain and sprocket gearing to a flywheel 24 ft. in diameter weighing 60,000 lbs. The weight of the paddles is 17,920 lbs. The newspaper account from which we take the above states that this weight acts through a distance of 8 ft. on the average, giving 143,360 ft. lbs., which multiplied by the 32 impulses per minute gives 45,000,000 ft. lbs. per minute, or about 135 HP. This method of estimating the horse power is evidently fallacious. The larger part of the weight of the paddles is no doubt supported from the overhead shaft, and swinging a weight so supported through an arc of 8 ft. is a very different thing from raising the weight 8 ft. high, which would be required to give the foot-pounds stated.

ACETYLENE GAS is being experimented with in Paris as a means of lighting omnibuses. The gas generator, weighing about 26 lbs., is placed upon the back platform, under the stairway leading to the top-seats. This generator will produce about 1 cu. m. of gas from one charging; but as recent photometric measurements make the acetylene gas give about 15 times more light than ordinary gas, this amount provides sufficient light for one trip. The gas is produced from water and calcium carbide, the generator being so arranged as to furnish the gas in a manner exactly proportioned to the consumption under a pressure of only 5.2 ins. of water. The light is sufficiently bright to permit the reading of newspapers, and there is no odor. The new light has been too recently introduced to permit any close estimates as to its actual economy, but the cost is said to be less than that of light from petroleum lamps. The electric accumulators, previously tried, weighed 275 lbs., and the sulphuric acid solution employed was easily spilled and gave trouble.

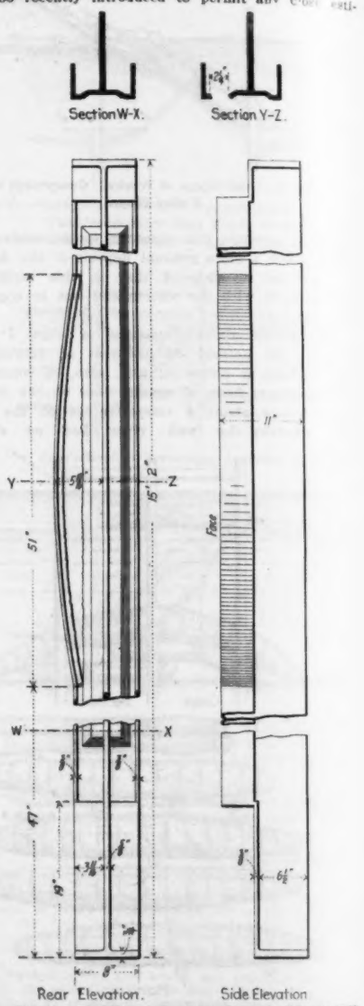

Fig. 2.—Details of Mullion, Showing General Appearance of Fracture, Siegel-Cooper Building, New York City.

ACETYLENE GAS is condemned by the New York Board of Fire Underwriters. As the result of a report made to it by Dr. Henry Morton, President of the Stevens Institute of Technology, the board has resolved not to insure any building in which acetylene gas is regularly used. Prof. J. M. Crafts, of the Massachusetts Institute of Technology, in a lecture before the Society of Arts, in Boston, states that acetylene gas forms more readily than other gases an explosive mixture with air, 5 to 6% of acetylene and 10 to 12% of water gas, respectively, being required to explode with air. The danger is enhanced by the low temperature at which the acetylene mixture takes fire, 429° C., mixtures of air with other gases requiring 600° C. While pure acetylene gas is not poisonous, the commercial article may be, due to the possibility of its containing phosphoretted hydrogen, derived from phosphorus in the lime and in the coke used in the production of calcium carbide. It is also possible that other poisonous gases, such as arseniuretted hydrogen, may be contained in commercial acetylene, but these impurities could probably be removed by a proper treatment of the gas.